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final briefing

SPACE STATION NEEDS, ATTRIBUTES, AND ARCHITECTURAL OPTIONS

part 1 - summary

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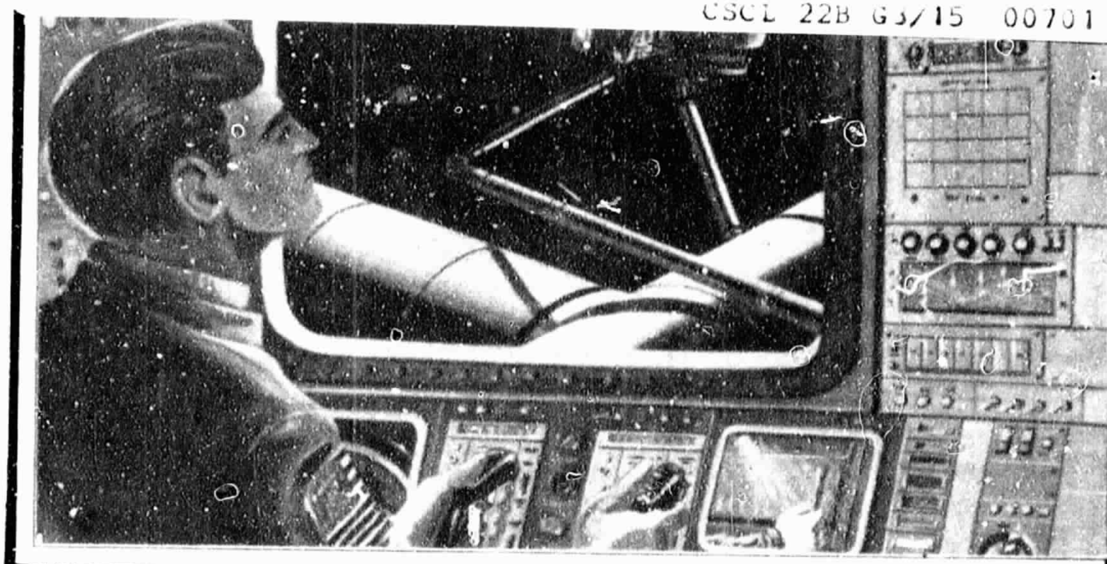

COMSAT GENERAL GRUMMAN GENERAL ELECTRIC

final briefing

SPACE STATION NEEDS, ATTRIBUTES, AND ARCHITECTURAL OPTIONS

part 1 - summary

prepared for
National Aeronautics and Space Administration
Headquarters
Washington, D.C. 20546

under contract NASW-3685
Space Station Task Force
Contracting Study Project Manager — E. Brian Pritchard

prepared by
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Bethpage, NY 11714

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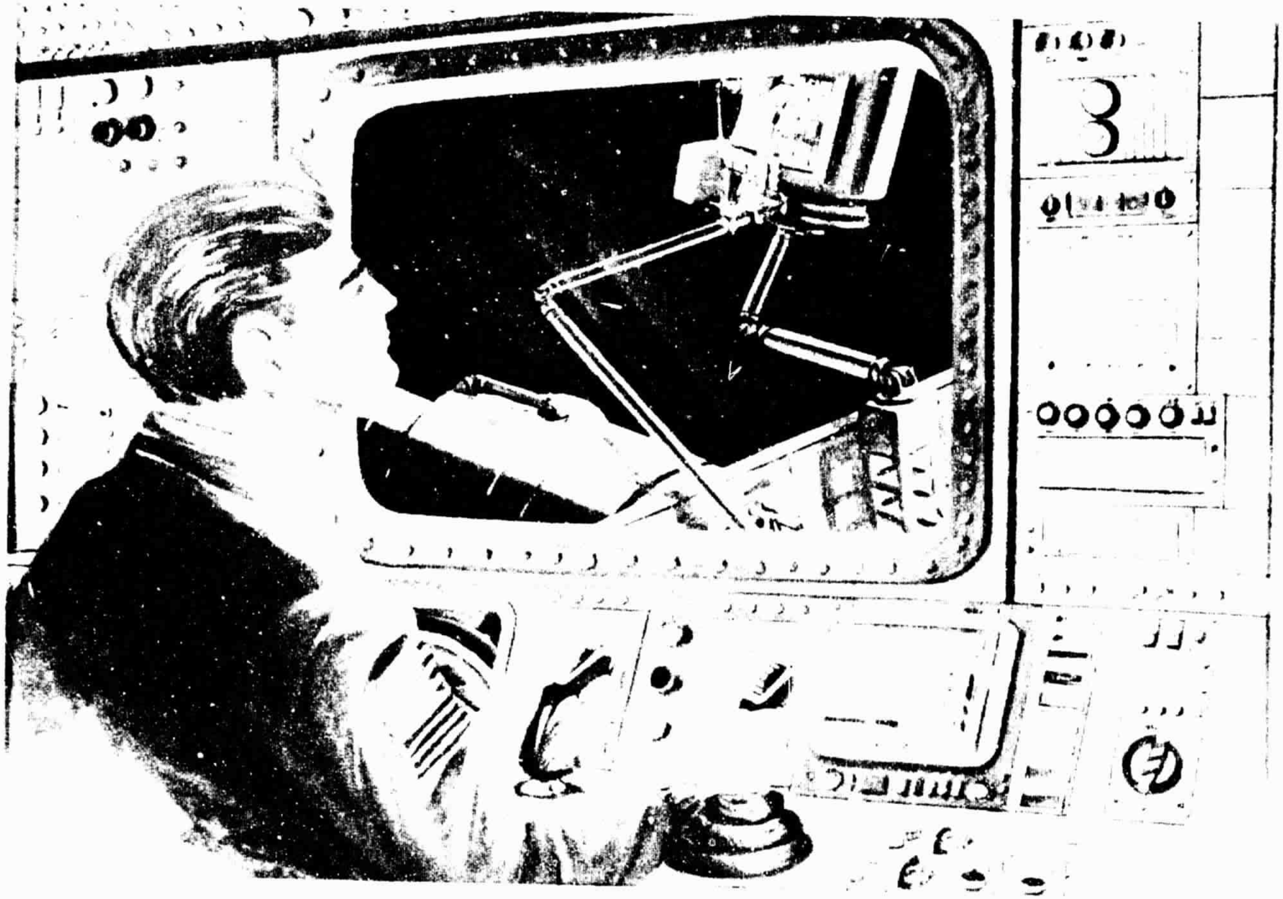
5-9 April 1983

SPACE STATION NEXT MAJOR SPACE INITIATIVE



GRUMMAN

GENERAL ELECTRIC

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SPACE STATION

FINAL SUMMARY BRIEFING AGENDA

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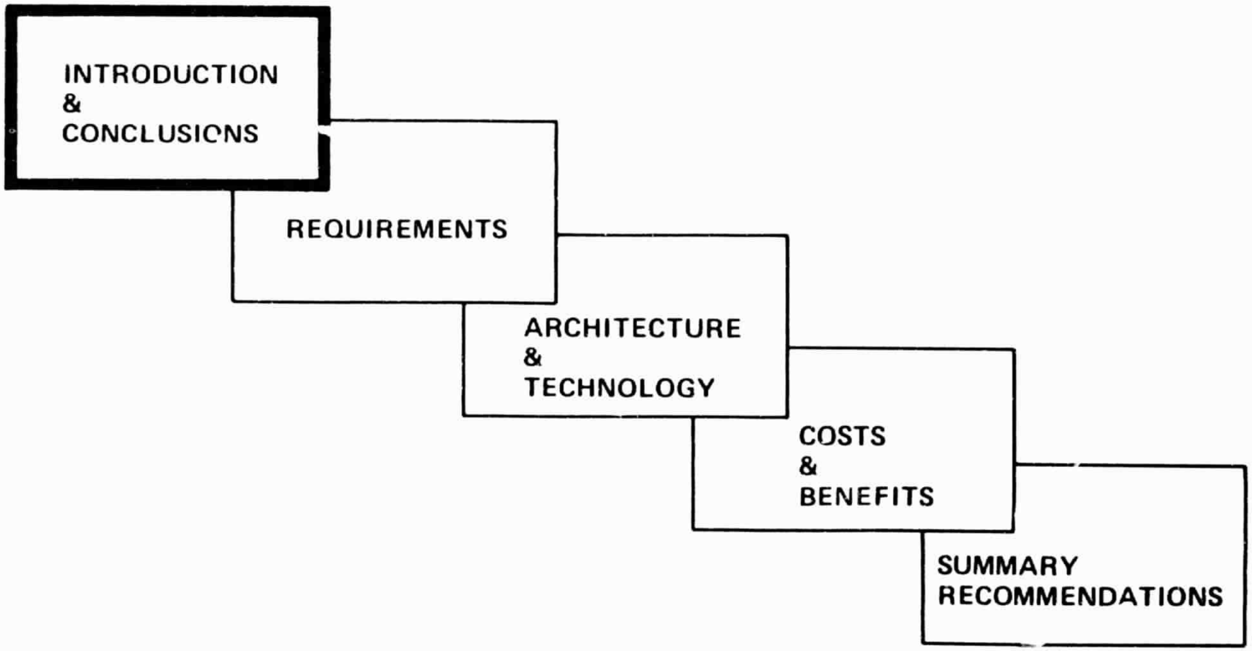

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SPACE STATION PROGRAM ORGANIZATION

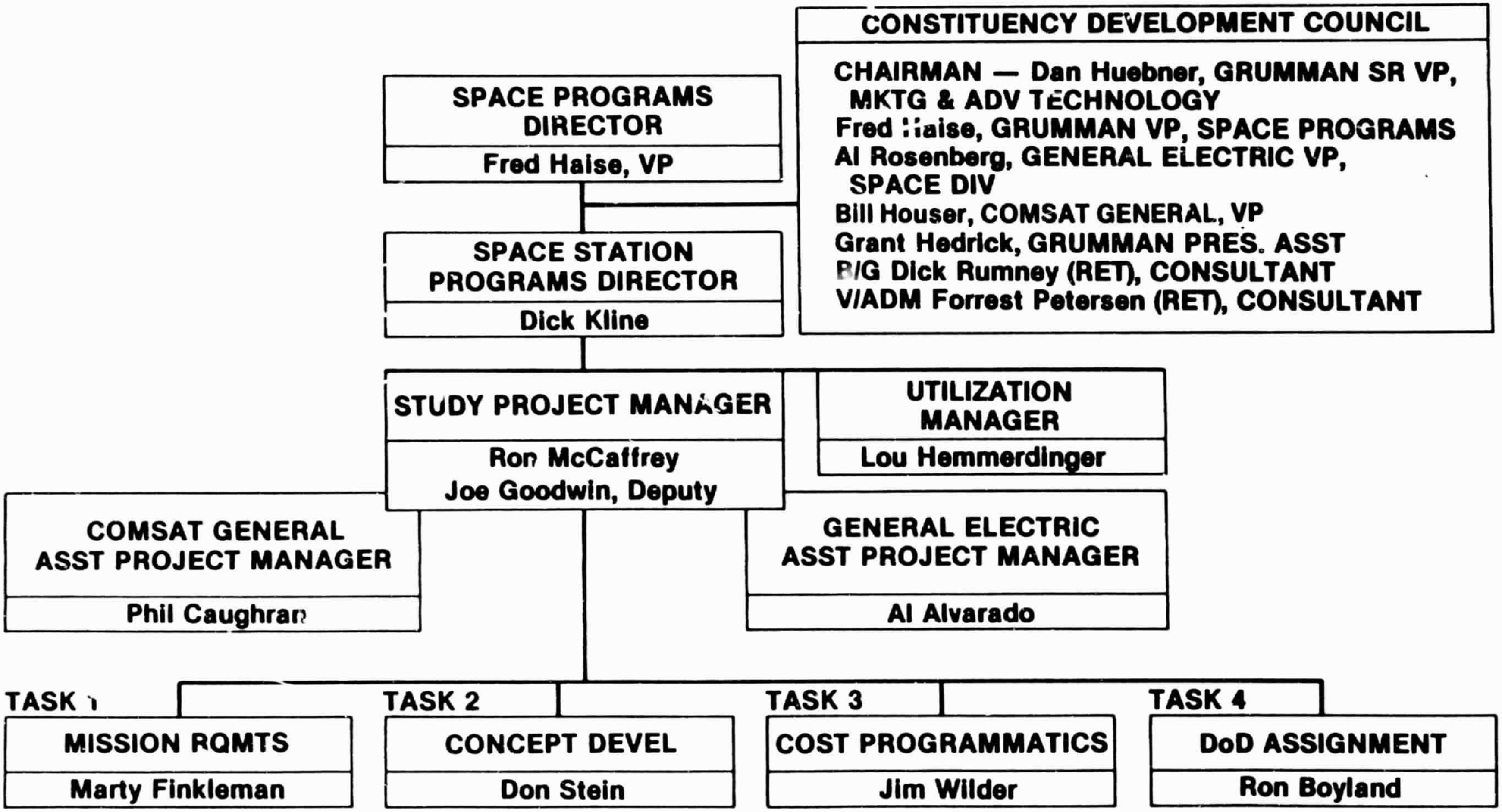
This contract was performed under Grumman's Space Programs Directorate headed by Vice President Fred Haise, and within the Space Station Programs organization directed by Dick Kline. As shown on the facing page, Grumman Project Study Manager was Ron McCaffrey, who in turn was assisted by Deputy Project Manager Joe Goodwin and the Assistant Project Managers Al Alvarado for General Electric and Phil Caughran for COMSAT General. Significant contributions were made to the Grumman study effort by its two teammates:

- COMSAT General defined Space Station requirements and benefits for commercial communication satellites and defined the on-board RF communication subsystem.
- General Electric, in turn, defined Space Station requirements and benefits for selected areas of science and applications, commercial processing and remote sensing, and national security missions. In addition, they defined architectural concepts for the data management subsystem.

Technical progress of the Grumman team was periodically reviewed during the study by a seven-member intercompany Constituency Development Council (CDC). Members of this group are listed on the facing page. The CDC also provided guidance to parallel corporate-funded activities to develop Space Station advocates and constituents within non-aligned commercial companies. Lou Hemmerdinger, Manager for Space Station Utilization, led Grumman's efforts in this area.

SPACE STATION PROGRAM ORGANIZATION

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL



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CORPORATE SUPPORT

Each of the three companies, Grumman, General Electric and COMSAT General provided additional management and technical support over and above the contracted study. The Constituency Development Council, chaired by Grumman, had vice presidential representation from each of the companies, in addition to consultants involved in technology, Air Force and Navy programs. This group formulated plans, strategy and further development of a constituence from the user community. Incorporation and use of the G.E. Corporate Advisory Board and establishment of the COMSAT General Space Station Review Board were fallouts from the initial council meeting. These corporate boards were used to promote and review technologies for constituent development, within and outside of respective companies.

Contacts with foreign companies were made during the proposal preparation and these were continued throughout the contract period. Presentation by these companies defined hardware elements of interest in support of the Space Station, European Space Station study progress and proposed European/U.S. cooperative efforts for a Space Station.

CORPORATE SUPPORT

- EXECUTIVE LEVEL PARTICIPATION
  - CONSTITUENCY DEVELOPMENT COUNCIL
  - GE TECHNOLOGY COUNCIL & CORPORATE ADVISORY BOARD
  - COMSAT GENERAL SPACE STATION REVIEW BOARD
- COORDINATED USER ALIGNMENT ACTIVITY
  - CORPORATE AND R&D LEVEL FOCUS
  - FACE-TO-FACE MEETINGS
- CONTRIBUTIONS FROM
  - BRITISH AEROSPACE: PALLETS, SOLAR ARRAYS, & COMM SATS INFORMATION
  - DORNIER: ROSAT, MPS, BIORACK, IPS, & RADIATORS INFORMATION
  - ERNO/MBB: EURECA, SPACE LAB, LIFT SCIENCES, SPACE PLATFORM, & TECHNOLOGY TRENDS.

CORPORATE SUPPORT

- EXECUTIVE LEVEL PARTICIPATION
  - CONSTITUENCY DEVELOPMENT COUNCIL
  - GE TECHNOLOGY COUNCIL & CORPORATE ADVISORY BOARD
  - COMSAT GENERAL SPACE STATION REVIEW BOARD
- COORDINATED USER ALIGNMENT ACTIVITY
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  - FACE-TO-FACE MEETINGS
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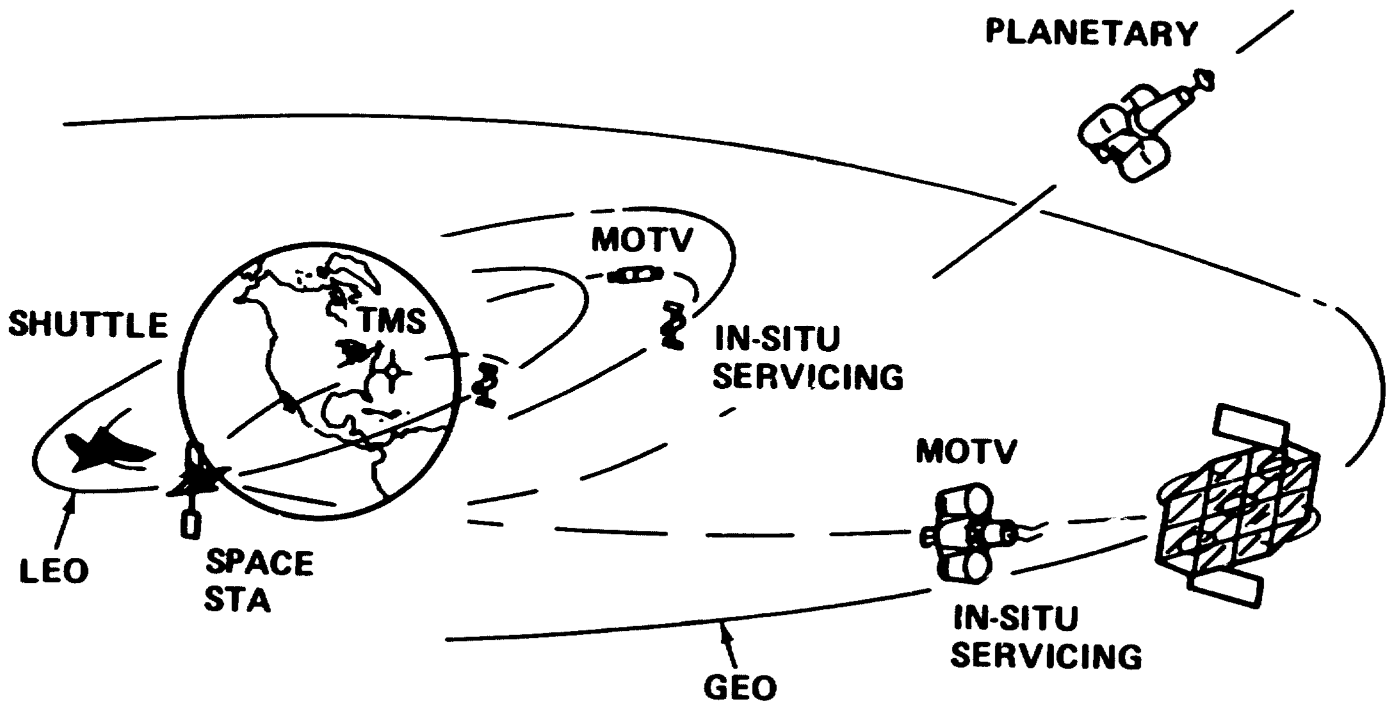
  - ERNO/MBB: EURECA, SPACE LAB, LIFT SCIENCES, SPACE PLATFORM, & TECHNOLOGY TRENDS.

SPACE STATION ARCHITECTURE

The next U.S. Space Station must be more than "man-in-the-can" and thus must go beyond previous Space Station programs (i.e., Skylab and Salyut). We recommend that the U.S. establish a permanent manned presence in space that allows dramatic expansion of our capability to operate in geostationary and other useful orbits. A step toward domination of orbits opens a gateway to future endeavors that could not otherwise be attempted.

SPACE STATION ARCHITECTURE

THE U.S. SHOULD ESTABLISH A PERMANENT MANNED PRESENCE IN SPACE & DRAMATICALLY EXPAND OUR CAPABILITY TO OPERATE IN GEOSTATIONARY & OTHER USEFUL ORBITS



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CONCLUSIONS

The Initial Space Station should be manned, placed in 28.5 deg orbit, and provide capabilities which include space test facility, satellite service, transport harbor and observatory. A space industrial park may be added in the future, once further development effort validates the cost and expanding commercial market for space-processed material. Using the Space Station as a national space test facility will enhance national security, commercial and scientific interests alike.

The initial Space Station should provide capabilities with high payoff in economic, performance and social benefits. Benefits include the lowering of acquisition costs for NASA and DoD space assets and a basis for broadening international participation.

A vigorous Space Station program will not only rekindle national interest and education in science and engineering, but will also provide a basis for broadening international cooperation.

CONCLUSIONS

- SPACE STATION HAS HIGH PAYOFF FOR
  - SPACE TEST FACILITY
  - TRANSPORTATION HARBOR
  - SATELLITE SERVICES/ASSY
  - OBSERVATORY
  - INDUSTRIAL PARK

- CONTRIBUTES TO NATL SECURITY & WORLD PEACE
- STIMULATES COMMERCIAL SECTOR
- SHARPENS CUTTING EDGE OF TECHNOLOGY

- ARCHITECTURE DEVELOPMENT
  - INITIAL STEP TO CONTRIBUTE TO ALL FOUR HIGH PAYOFF FUNCTIONS
  - PARTICULAR ACCOMMODATION OF DoD & COMMERCIAL NEEDS IN "SPACE TEST FACILITY"
  - INCORPORATE ARIANE, EURECA IN INFRASTRUCTURE

- VIGOROUS GROUND & SHUTTLE FLIGHT DEMO PROGRAM REQUIRED IN 80's TO DEMONSTRATE CAPABILITY

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FINAL SUMMARY BRIEFING
AGENDA

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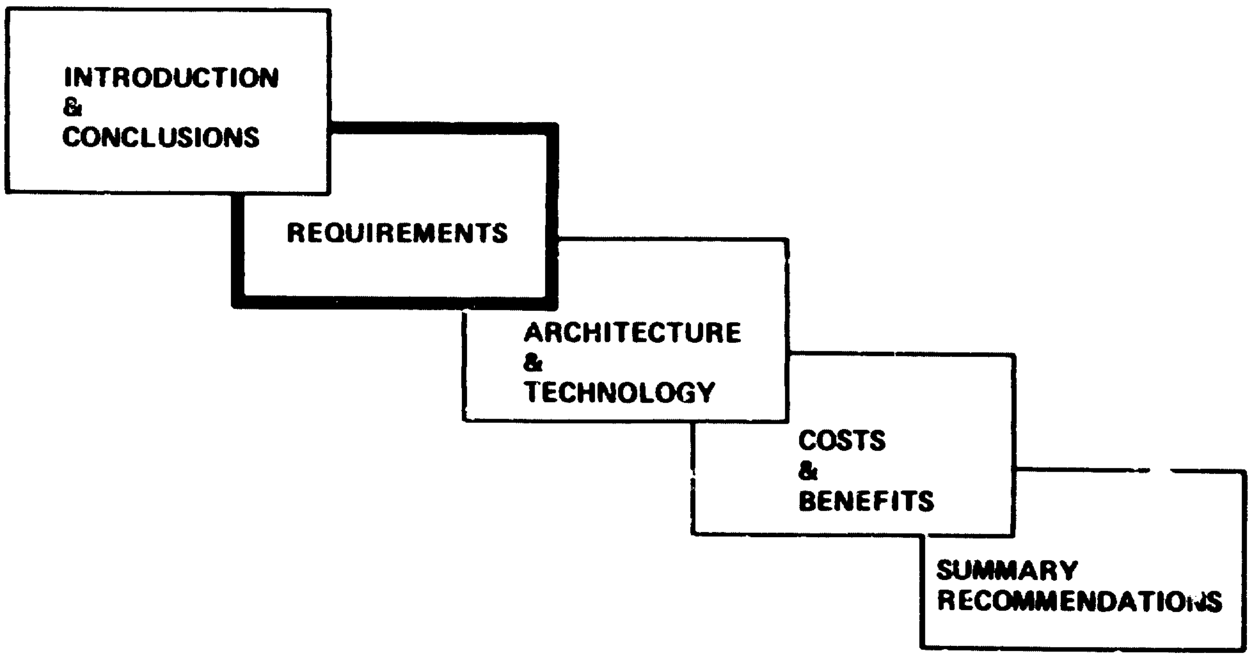

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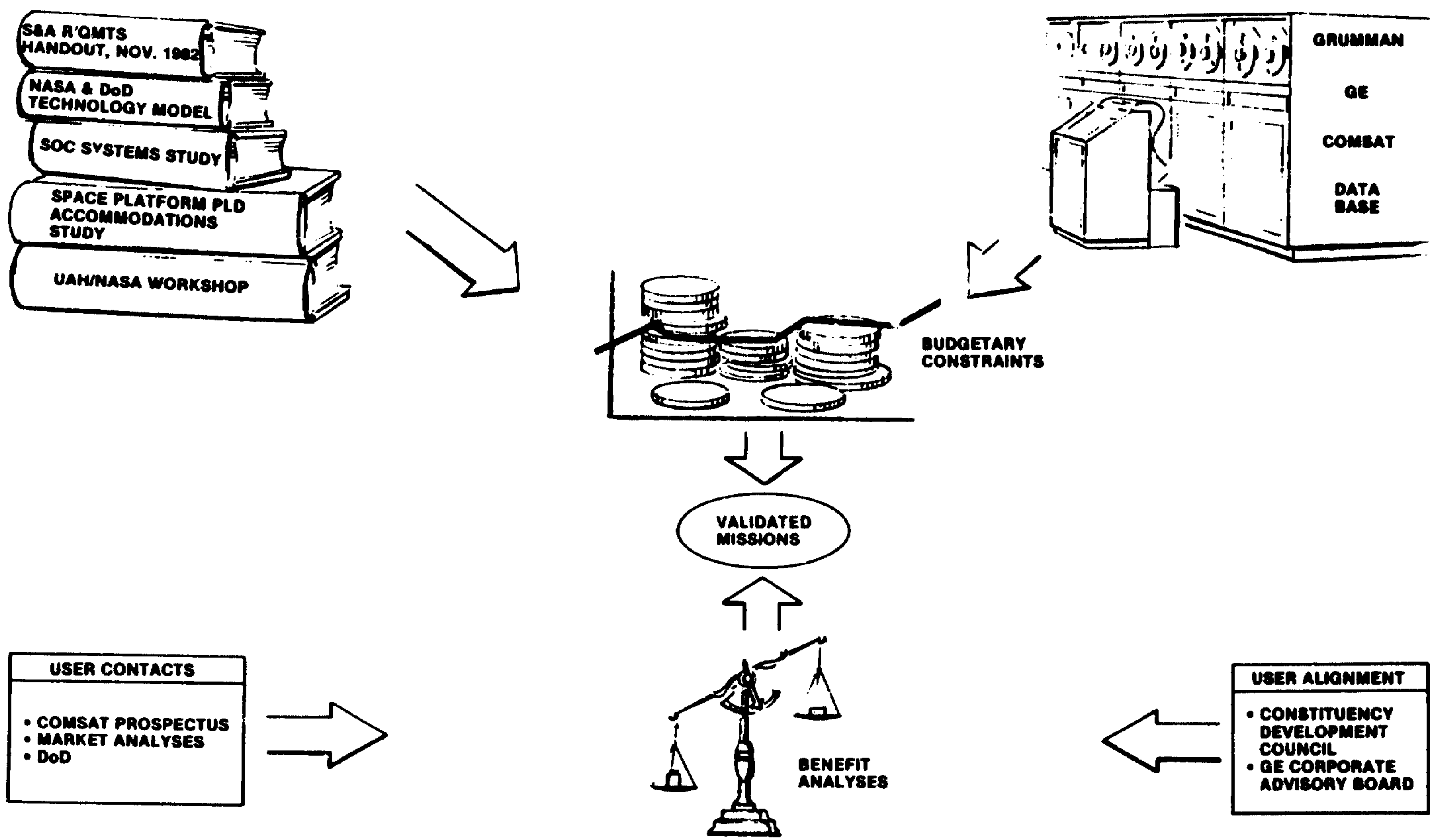
MISSION VALIDATION

One of the key objectives of the Grumman team was the validation of missions and associated requirements. As illustrated on the opposite page the Grumman team used a library of related documentation, a comprehensive data base, extensive user contacts and vigorous user alignment activities to achieve this objective. Examples of these activities included:

- COMSAT General prepared a prospectus document entitled, "Manned Space Station Relevance to Commercial Telecommunications Satellites." The prospectus was sent to 42 organizations; more than 50% of the organizations replied
- The Constituency Development Council (including Grumman, GE and COMSAT General corporate officers) guided parallel corporate-funded activities to develop Space Station advocates and constituents within non-aligned commercial companies
- The GE Space Station Corporate Advisory Board is spearheading an effort to develop an Industrial Research Facility on-board the Space Station.

All Space Station candidate missions were subjected to an evaluation/filtering process, which included the application of budgetary constraints and performance of benefit analyses.



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GRUMMAN TEAM RESPONSIBILITIES

The combined technical expertise and resources of Grumman and its team members, General Electric and COMSAT General, were used to perform the mission requirements task. The division of responsibilities, by mission category is as shown on the facing page.

SPACE STATION

GRUMMAN TEAM RESPONSIBILITIES

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL

MISSIONS	GRUMMAN	GENERAL ELECTRIC	COMSAT
• SPACE OPERATIONS	✓		
• NATIONAL SECURITY	✓	✓	
• COMMERCIAL			
– COMMUNICATIONS			✓
– MATERIAL PROCESSING	✓	✓	
– EARTH OBSERVATION		✓	
• SCIENCE & APPLICATION			
– ASTROPHYSICS	✓		
– LIFE SCIENCES		✓	
– SOLAR TERRESTRIAL & EARTH OBSERVATION	✓	✓	
– MATERIAL SCIENCE		✓	
– PLANETARY	✓		
TECHNOLOGY DEVELOPMENT	✓		

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CONSTITUENCY DEVELOPMENT

The Utilization office is comprised of a manager from Grumman and his deputy from General Electric. Each company provides its own marketing and research support for all contacts.

Three separate organizations directly support the Utilization office and are called upon in varying degrees to make contacts where appropriate.

The Constituency Development Council, previously described, may be called upon to make contacts at any of the areas of interest. The G.E. Corporate Advisory Board meets monthly to define potential commercial areas of interest and contacts within the G.E. organization. The board is comprised of 12 members nine of whom are from different commercial divisions within the company. The five Grumman Corporate regional offices act as separate marketing arms covering the major sections of the U.S., making the initial contacts with potential clients.

Our strategy is to uncover new imaginative uses of space from our university and generic lab contacts, utilize associations to provide leads and spread the word about space and the Space Station and make commercial contacts at medium to large size companies having an interest in high technology products.

CONSTITUENCY DEVELOPMENT

FROM

- CONSTITUENCY DEVELOPMENT COUNCIL
- GE CORPORATE ADVISORY BOARD
- GRUMMAN CORP REGIONAL OFFICES
  - WASHINGTON, DC
  - ATLANTA
  - DALLAS
  - CHICAGO
  - LOS ANGELES

VIA

UTILIZATION OFFICE
- L. HEMMERDINGER (GRUMMAN)
- J. DICKINSON (GE)
  - MARKETING
  - RESEARCH
  - ENGINEERING

TO

ORGANIZATIONS
- COMMERCIAL COMPANIES
  - PHARMACEUTICALS
  - METALS
  - SEMICONDUCTORS
- ASSOCIATIONS
- GENETIC LAB
- UNIVERSITIES
- GRUMMAN UNIV FORUM
- GOVERNMENT
- FOREIGN

INDIVIDUALIZED MTGS
- SPACE STATION OVERVIEW
- PRESENTATION OF USES OF SPACE
- FOLLOW-UP DISCUSSIONS

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VALIDATION/SELECTION OF MISSIONS

The flow depicted in this chart indicates the steps taken in the process of validating and selecting the GE missions that were included in the Space Station Mission Model. Initially, many candidate missions were identified from available sources and user contacts. An initial analysis of the mission characteristics and requirements was performed on these missions, to permit the identification of those that should merit further consideration in the study. The filtering process considered the suitability of the equipment and operations required by the mission, relative to the general guidelines and characteristics of a multi-disciplinary manned Space Station. In addition, the filtering process took into consideration the benefits associated with the mission, if conducted on-board the Station. Those that passed the filtering process were analyzed in more detail and documented for inclusion in the Final Report (Volume II, Book 1, Part II).

The lower part of the chart depicts the final selection of missions, performed by Grumman in conjunction with the GE team, taking into consideration the overall system aspects of the evolutionary Station and associated constraints and commonalities.

VALIDATION/SELECTION OF MISSIONS

SURVEY OF MISSION CANDIDATES → INITIAL DEFINITION OF MISSION REQUIREMENTS → ANALYSIS OF MISSION/STATION SUITABILITY → BENEFITS ANALYSIS → DEFINITION OF RECOMMENDED SPACE STATION MISSIONS

LEADING TO:

SELECTION OF MISSIONS BASED ON:

- SPACE STATION MODELING
- ARCHITECTURAL OPTIONS
- BUDGET CONSTRAINTS
- PRIORITY OF MISSIONS
- MISSION COMMONALITY

MISSION VALIDATION PROCESS

This chart is a further elaboration of the previous one, showing the various factors that were considered in each of the validation steps, both for the commercial missions and the science and application (S&A) missions. Particularly interesting in these considerations are the differences between the key factors attendant to the commercial and science and application missions. Examples of these differences are as follows:

- **Survey of Mission Candidates** - Identification of the commercial missions emphasized user contacts, whereas the S&A missions used existing sources of data
- **Initial Definition of Mission Requirements** - Proprietary considerations are important in the commercial missions, particularly in materials processing, where the several proprietary processes are handled in the same flight
- **Benefits Analysis** - Commercial missions benefits are more quantitative than those of S&A missions, due to the profit objective which is associated with commercial ventures. In addition, the competing ground-based program must be considered in the benefits projection, since the analysis must consider what portion of the market could be captures by processing in space vs future processing on the ground that can eliminate the effects of gravity
- **Definition of Recommended Missions** - The format used in documenting the mission definitions is different in the commercial missions vs that in the S&A missions, due to the emphasis on market potential for the commercial missions.

MISSION VALIDATION PROCESS

	SURVEY OF MISSION CANDIDATES	INITIAL DEFINITION OF MISSIONS REQUIREMENTS	ANALYSIS OF MISSION/ STATION SUITABILITY	BENEFITS ANALYSIS	DEFINITION OF RECOMMENDED SPACE STATION MISSIONS
COMMERCIAL	* USER CONTACTS • USER NEEDS • PREVIOUS SURVEYS • CONSULTANTS * INDUSTRY GOALS	• MISSION FUNCTIONS • EQUIPMENT CONCEPTS • ORBIT & OPERATIONS • IMPLEMENTATION OPTIONS * PROPRIETARY CONSIDERATIONS	• TIME FRAME & TECHNOLOGY • INTERACTION WITH OTHER MISSIONS • REQ'T FOR UNIQUE ORBITS • USE OF STATION ATTRIBUTES • UTILIZATION OF MAN	• COST COMPARISONS * PROFITABILITY * USER CONSTITUENCY * PROJECTED GROUND BASED TECHNOLOGY	DEFINITION INCLUDES: • MISSION BACKGROUND • MARKET ANALYSIS • MISSION DESCRIPTION • REQUIREMENTS • BENEFITS
SCIENCE/APPLICATIONS	• SPACE STATION INDUSTRY BRIEFINGS • NASA PLANS • AVAILABLE LITERATURE/ SURVEYS • SCIENTIFIC NEEDS • IN-HOUSE EXPERTISE & CONSULTANTS	• MISSION FUNCTIONS • EQUIPMENT CONCEPTS • ORBIT & OPERATIONS • IMPLEMENTATION OPTIONS	• TIME FRAME & TECHNOLOGY • INTERACTION WITH OTHER MISSIONS • REQ'T FOR UNIQUE ORBITS • USE OF STATION ATTRIBUTES • UTILIZATION OF MAN * INTERNATIONAL SCIENTIFIC MISSIONS	• COST COMPARISONS * SOCIAL BENEFITS * PERFORMANCE BENEFITS (SCIENCE)	DEFINITION INCLUDES: • DESCRIPTION • SELECTION RATIONALE • ACCOMMODATION REQ'TS • S.S. IMPLEMENTATION APPROACH • ALTERNATIVE IMPLEMENTATION APPROACH • BENEFITS

* INDICATES UNIQUE CONSIDERATION FOR COMMERCIAL OR SCIENCE/APPLICATIONS

BENEFICIAL ATTRIBUTES IN VARIOUS DISCIPLINES

This chart summarizes our findings relative to the ways in which the Station will be beneficial in the various disciplines that GE analyzed. Many of these benefits apply across several disciplines; for instance, there is a cost advantage associated with missions in each of the disciplines, as will be quantitatively discussed later in this presentation.

The three earth observation disciplines show several common benefits related, for instance, to the enhanced accommodation capability available in the integral station and man-tended platforms. Related to this expanded capability are two other benefits: 1) the performance benefits that accrue from concurrent multidisciplinary measurements; and 2) the Station will provide a focus of activity for a very large scientific and application community, whose interaction will bring forth new ideas and scientific approaches. In addition, the earth observation disciplines benefit from the added flexibility afforded by the ability of the crew to change and modify the instruments during long-term observation periods.

In all earth observations, but particularly those related to dynamic atmospheric and oceanographic phenomena, man has a decided contribution in terms of selecting targets, instruments and observational parameters.

Concerning Life Sciences, the main advantage of the Space Station is the ability to expose the human subjects to long-term periods of near-zero gravity. In addition, the astronaut's performance and physical condition can be studied under actual working conditions in a very active and varied working environment.

SPACE STATION

BENEFICIAL ATTRIBUTES IN VARIOUS DISCIPLINES

GRUMMAN
GENERAL ELECTRIC
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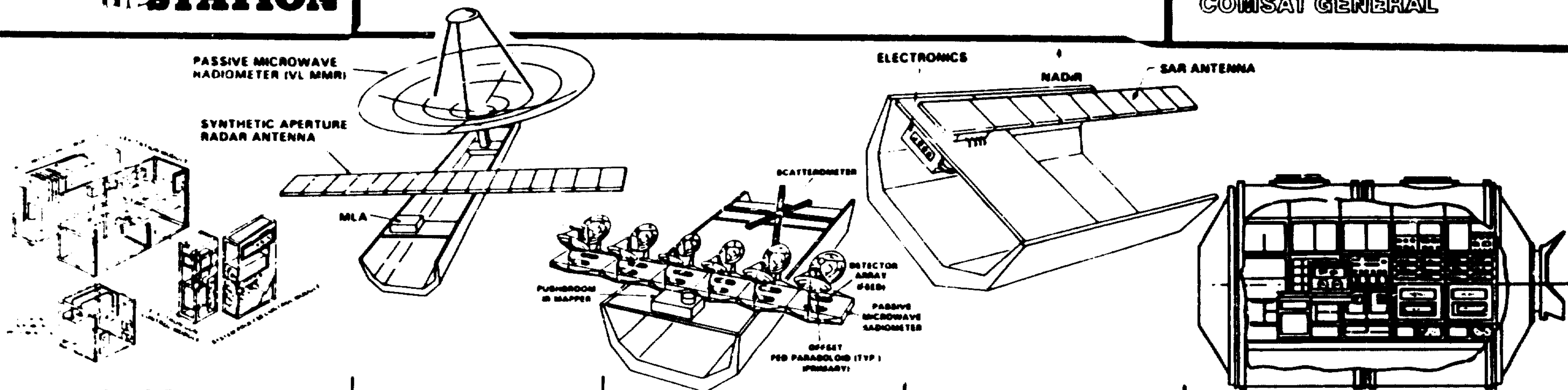

MATERIALS PROCESSING	SOLAR/ TERRESTRIAL	GLOBAL ENVIRONMENT	RESOURCE OBSERVATION	LIFE SCIENCES

MATERIALS PROCESSING
- CENTRALIZED LARGE POWER SOURCE
- MANNED CONTROL OF PROCESSES
- ACCOMMODATION OF LARGE STRUCTURES
- LONG DURATION MICROGRAVITY

SOLAR/TERRESTRIAL, GLOBAL ENVIRONMENT, RESOURCE OBSERVATION
- MULTI-INSTRUMENT ACCOMMODATION
- FLEXIBILITY TO CHANGE/MODIFY INSTRUMENTS
- SYNERGISM BETWEEN CONCURRENT MEASUREMENTS
- FOCUSING OF EARTH OBSERVATION RESEARCH

GLOBAL ENVIRONMENT, RESOURCE OBSERVATION
- MANNED OPTIMIZATION OF DATA ACQUISITION

GLOBAL ENVIRONMENT
- ERECTION OF LARGE ANTENNAS

LIFE SCIENCES
- LONG-TERM EX-POSURE TO NEAR ZERO G
- MULTI-MANNED CAPABILITY
- ASSESSMENT OF MANNED CAPABILITIES

COST ADVANTAGE OF MISSION IMPLEMENTATION ON THE SPACE STATION

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CORPORATE INVOLVEMENT IN THE MISSION VALIDATION PROCESS

One of our aims in the study was to use the broad-based experience of the General Electric Company in the development of the mission requirements. For this purpose, the Corporate Advisory Board (CAB) was established to provide a broad industrial view of the study progress and results. In particular, we wanted to factor in the perspective of other sectors of the company relative to space commercialization.

This chart lists the various sectors of the company that were represented in the CAB. The chairman, Dr. Bill Sheerán, selected the membership on the basis of our study needs. Thus, we have representatives from groups under these sectors, including Medical Systems, the Motor Business Group, and the Silicone Products Business Group. The CAB met periodically during the study and provided insight regarding the industrial perspective of space commercialization, new ideas for missions and a review of the mission definitions. At the recommendation of the CAB, a team of Corporate Research and Development experts is performing a company-funded study to recommend the type of materials processing investigations that should be performed in a Space Station Laboratory for Industrial Research.

CORPORATE INVOLVEMENT IN MISSION VALIDATION PROCESS

GE CORPORATE ADVISORY BOARD

- CORPORATE RESEARCH & DEVELOPMENT
- TECHNICAL SYSTEMS SECTOR
- INDUSTRIAL PRODUCTS SECTOR
- CONSUMER PRODUCTS SECTOR
- AIRCRAFT ENGINE BUSINESS GROUP
- SERVICES & MATERIALS SECTOR
- POWER SYSTEMS SECTOR
- TECHNOLOGY COUNCIL

INDUSTRIAL PERSPECTIVE (e.g)

- BUSINESS ASPECTS
- INDUSTRY NEEDS
- EVOLVING GROUND BASED TECHNOLOGY

NEW IDEAS (e.g.)

- VAPOR DEPOSITION FOR 3-D CIRCUITS
- CONTAINERLESS MELTING APPLICATIONS

REVIEW OF MISSIONS (e.g.)

- PRIORITIES
- FEASIBILITY
- REFERRALS TO TECHNICAL EXPERTS

COMMERCIAL COMMUNICATIONS SATELLITE MISSIONS

The commercial telecommunications satellite industry is a leading potential user of the Space Station in the 1990s, providing that the Space Station can demonstrate benefits with respect to mission cost and risk. The overriding concern of this industry is economical access to geosynchronous orbit. As satellites inevitably become heavier and more complex, the use of a low orbit Space Station as a facility for checkout, repair, fueling and possibly assembly and integration prior to raising to GEO is likely to become increasingly attractive to the various communities of interest involved, including system users, owners, investors and insurers.

A forecast of commercial satellite missions to the turn of the century was developed, taking into account underlying end-user demand, replacement and expansion of existing systems, new systems (such as direct broadcast), investment costs, technology improvements (allowing higher capacity and longer lifetimes), frequency band saturation, orbital arc spacing, and competitive and institutional trends. The forecast assumes the existence of credible foreign competion in launch services, and the NASA will capture 45% of the market for international satellite missions (Intelsat, Inmarsat), 95% of U.S. domestic communications missions and 35% of foreign regional communications missions.

COMMERCIAL COMMUNICATIONS SATELLITE MISSIONS

FORECAST IDENTIFIED 377 SATELLITE MISSIONS IN GEO, 1982 – 99

53 INTERNATIONAL COMMUNICATIONS 148 US DOMESTIC COMMUNICATIONS 176 FOREIGN REGIONAL COMMUNICATIONS	FREE WORLD TOTAL

OF THESE, 227 MISSIONS ARE LIKELY TO BE LAUNCHED USING STS

66 MISSIONS	700 kg CLASS	TOTAL MASS: 310 MT
35 MISSIONS	1000 kg CLASS	
82 MISSIONS	1500 kg CLASS	
37 MISSIONS	2300 kg CLASS	
7 MISSIONS	2800 kg CLASS	

BY THE MID-1990s NASA COULD "STOP" MOST MISSIONS AT A LEO SPACE STATION FOR CHECKOUT, REPAIR, FUELING, AND ASSEMBLY AND/OR INTEGRATION AS A ROUTINE PART OF ITS TRANSPORTATION SERVICES.

COMMERCIAL TELECOM SATELLITE INDUSTRY ACCEPTANCE OF SUCH USE OF SPACE STATION WILL DEPEND ON DEMONSTRATED BENEFITS WITH RESPECT TO MISSION COST AND RISK.

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SELECTED COMMERCIAL COMMUNICATIONS MISSIONS USING SPACE STATION

Space Station mission data sheets have been developed for four commercial communications missions of particular interest:

- R&D Laboratory - selected because such use may precede any use for operational missions
- Advanced International Satellite - selected because the benefits of low-orbit deployment and acceptance of Intelsat satellites in the generation VII/VIII time frame can most clearly be envisioned
- UF Sound Broadcast Satellite - selected because it is an example of an entirely new application for communications satellites that will require antennas so large as not to be adequately testable on the ground
- Land Mobile Satellite - selected because the predicted mass market for high quality communications to mobile vehicles in the U.S. can perhaps best be served by a combination of terrestrial and satellite transmission, and because, assuming available bandwidth restrictions, for an acceptable risk level, the large and complex antennas required could only be developed using a Space Station.

Both the sound broadcast and the land mobile satellite missions anticipate the development of satellite technology that may enable "personal communications services" in the early 21st century.

SPACE STATION

SELECTED COMMERCIAL COMMUNICATIONS MISSIONS USING SPACE STATION

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL

- RESEARCH AND DEVELOPMENT LABORATORY – EARLY 1990's
  - EXPERIMENTAL AREAS INCLUDE:
    - LG REFLECT. STRUCTURES
    - INTERSATELLITE LINKS
    - MOMENTUM WHEELS
    - FLUID IN DYNAMICS
    - ION THRUSTERS
    - PLUM IMPINGEMENT
- ADVANCED INTERNATIONAL SATELLITE – MID 1990's
  - TEST & REPAIR AS REQUIRED PRIOR TO RAISING TO GEO
  - POSSIBLE CUSTOMER ACCEPTANCE IN LOW ORBIT
  - INITIAL LAUNCH OF SATS SUITABLE FOR REMOTE SVCS IN GEO
- HF SOUND BROADCAST SATELLITE - MID 1990's
  - COMPLEMENT INTERNATIONAL BROADCASTING SERVICES
  - DEPLOY AND SERVICE SPACECRAFT STRUCTURAL ELEMENTS
  - SPOT BEAM IMPLEMENTATION COULD EMPLOY 300 m DIA ANT.
- LAND MOBILE SATELLITE – LATE 1990s
  - COMPLEMENT U.S. CVRG OR URBAN CELLULAR RADIO SYS.
  - PLAUSIBLE EVOLUTION LEADS TO 100 m DIA CLASS ANT.
  - SIGNIFICANT REVENUE POTENTIAL FORESEEN

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COMMERCIAL COMMUNICATIONS REQUIREMENTS VALIDATION

To realistically assess the importance of manned Space Stations in the context of commercial communications, Comsat General Prepared a document entitled, **"Manned Space Station Relevance to Commercial Telecommunications Satellites: A Prospectus to the Year 2000"** and circulated it to key representative organizations within the commercial telecommunications satellite and related communities of interest (including spacecraft manufacturers, commercial satellite owners, communications carriers, networks, risk insurers, investors, consultants and potential providers of launch services other than NASA). The intention in this undertaking was three-fold:

- To provide NASA with a forecast of future technology developments and satellite traffic, along with a description of those Space Station capabilities that would be beneficial to the commercial communications satellite industry
- To provide COMSAT General's views of the circumstances under which those capabilities are likely to be used
- To obtain an endorsement from the industry of the "prospectus" as written, or to identify points of major disagreement.

COMMERCIAL COMMUNICATIONS REQUIREMENTS VALIDATION

"PROSPECTUS" DOCUMENT CIRCULATED FOR COMMENT TO 42 KEY ORGANIZATIONS OF COMMERCIAL TELECOM SATELLITE INDUSTRY.

- 13 CARRIERS/NETWORKS
- 7 MANUFACTURERS
- 15 INSURERS
- 7 OTHER INVESTORS, (CONSULTANTS, ETC)

INCLUDED:

- FORECAST OF SATELLITE LAUNCHES & TECHNOLOGY IMPROVEMENTS
- SPACE STATION CAPABILITIES OF POTENTIAL INTEREST
- BENEFITS TO INDUSTRY OF USING SPACE STATION

RESULTS:

- 25 RESPONSES RECEIVED
- GENERAL SUPPORT OF COMSAT GENERAL POSITIONS & FORECASTS (80% OF RESPONDENTS)
- GENERAL SUPPORT OF THE SPACE STATION CONCEPT (INCLUDING IDEA THAT USE WILL DEPEND ON COST BENEFITS (68%))
- DIVERSITY OF WRITTEN FEEDBACK SHOULD BE HELPFUL IN NASA PLANNING

CANDIDATE MISSION INCREMENTAL BENEFITS

Benefit analyses were used to validate candidate missions. The question to be answered here was, "For a given mission, is there an economic advantage to "flying" the mission on a Space Station rather than, for example, as a Shuttle sortie mission or as a free flier?" The results for 39 representative missions are summarized opposite. About 57% of the cost savings came from commercial mission applications, 28% from national security missions, 8% from technology development missions and 7% from Science and Application missions.

These activities contributed to the mission validation process and provided a sound basis for establishing a baseline mission model as a realistic mission set.

SPACE STATION

CANDIDATE MISSIONS INCREMENTAL BENEFITS, FY '84 $M

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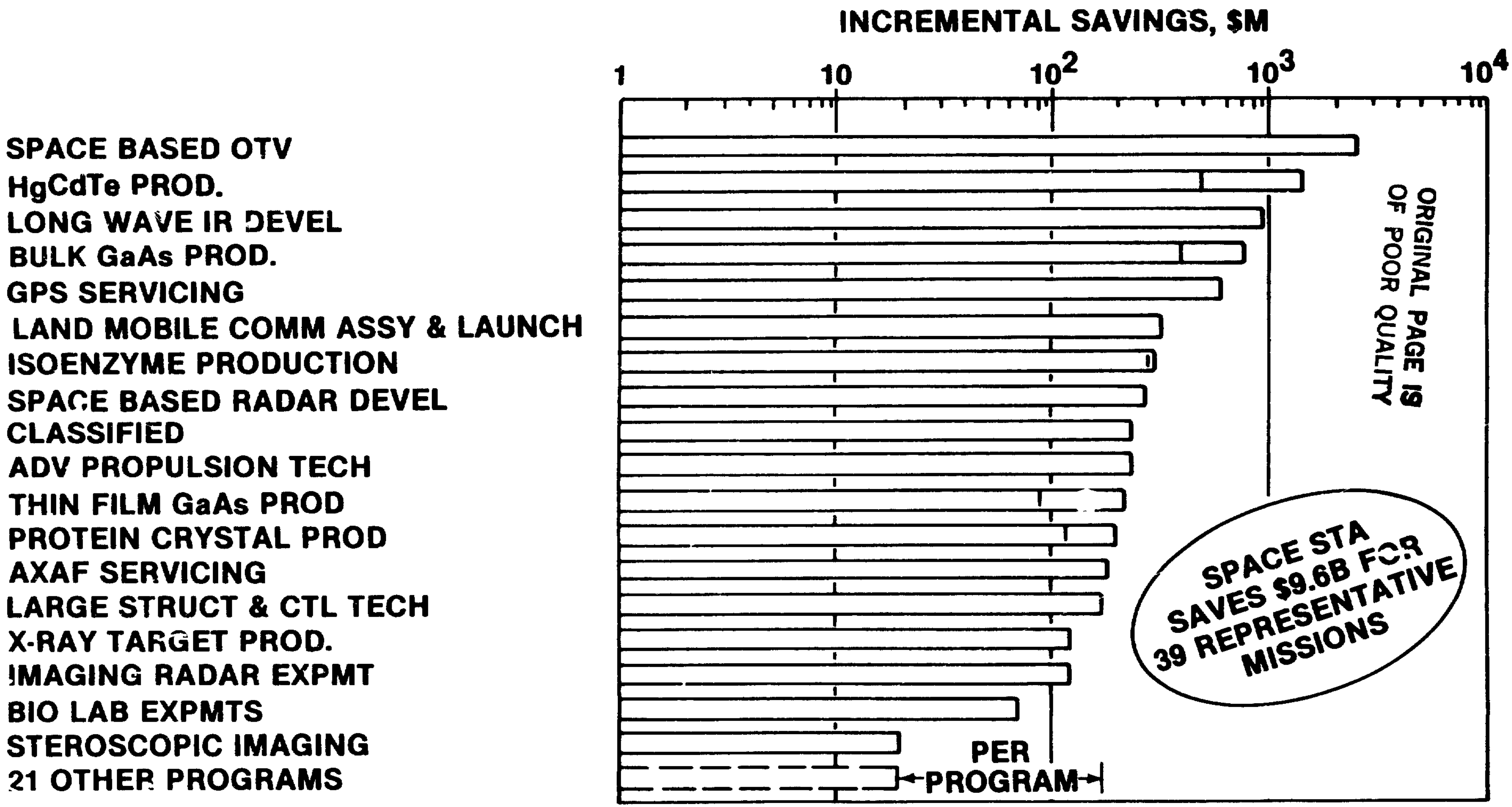
GENERAL ELECTRIC
COMSAT GENERAL



V83-0165-932(T)
G.H.

R-004,362.

SPACE STATION ROLES, COMMERCIAL MISSIONS

At the present time, essentially all commercial space missions have been communications satellites in geostationary orbit. Minor exceptions are a few materials processing missions that have flown or will fly in the near future. The demand for communications satellites certainly will continue, and materials processing and all areas of commercial R&D will inevitably expand. The commercial market for earth observations appears less obvious but should not be disregarded. The orbital needs are summerized opposite.

All of these missions except earth observations/meteorological may benefit from a low inclination earth orbit Space Station. Earth observations/meteorological desires a high-inclination orbit for complete global coverage and would benefit by sharing transport costs and facilities when compared to a dedicated platforms.

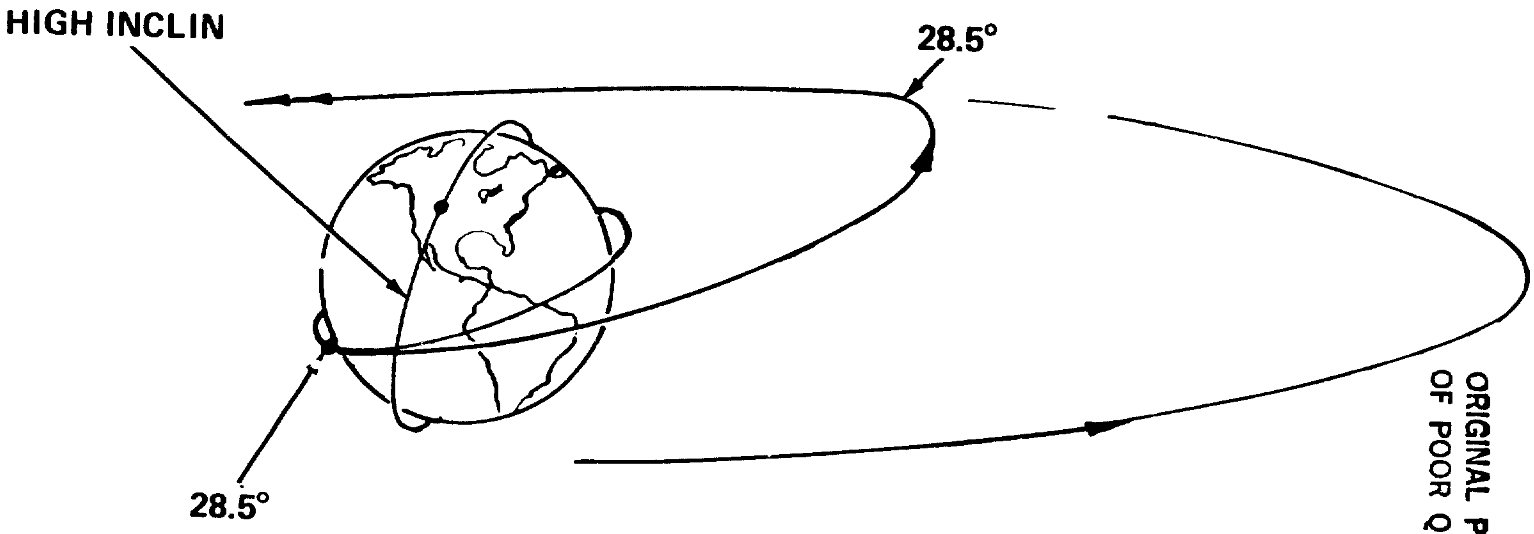
SPACE STATION

SPACE STATION ROLES, COMMERCIAL MISSIONS

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL

- OBSERVATIONS
  - MIN: COST BASE FOR WIDE COVERAGE DATA GATHERING

- COMMUNICATION
  - LOW COST TRANSPORT SATELLITES TO GEO



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- COMMUNICATION – LARGE ANTENNA ASSY, QUAL, ACCEPTANCE
- MATERIALS PROCESSING – MICRO G & LONG DURATION WITH MINIMUM COST
- R&D, ALL CATEGORIES – MANNED, LONG DURATION, SPACE TEST FACILITY

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R-004,362.

COMMERCIAL ACTIVITIES AT 28.5 DEG BASELINE MISSION MODEL

All commercial activities shown opposite may be done in the 28.5 deg orbit. Communications deployment to GEO desires the lowest inclinations, and R&D or materials processing activities have no orbital preference.

The communication missions involve component R&D, qualification of large antenna satellites and deployment of satellites to GEO with OTVs after 1993. All of these activities are external to the Space Station.

Materials processing activities consist of:

- Continuous R&D efforts to develop new processes and new products
- Production of developed products.

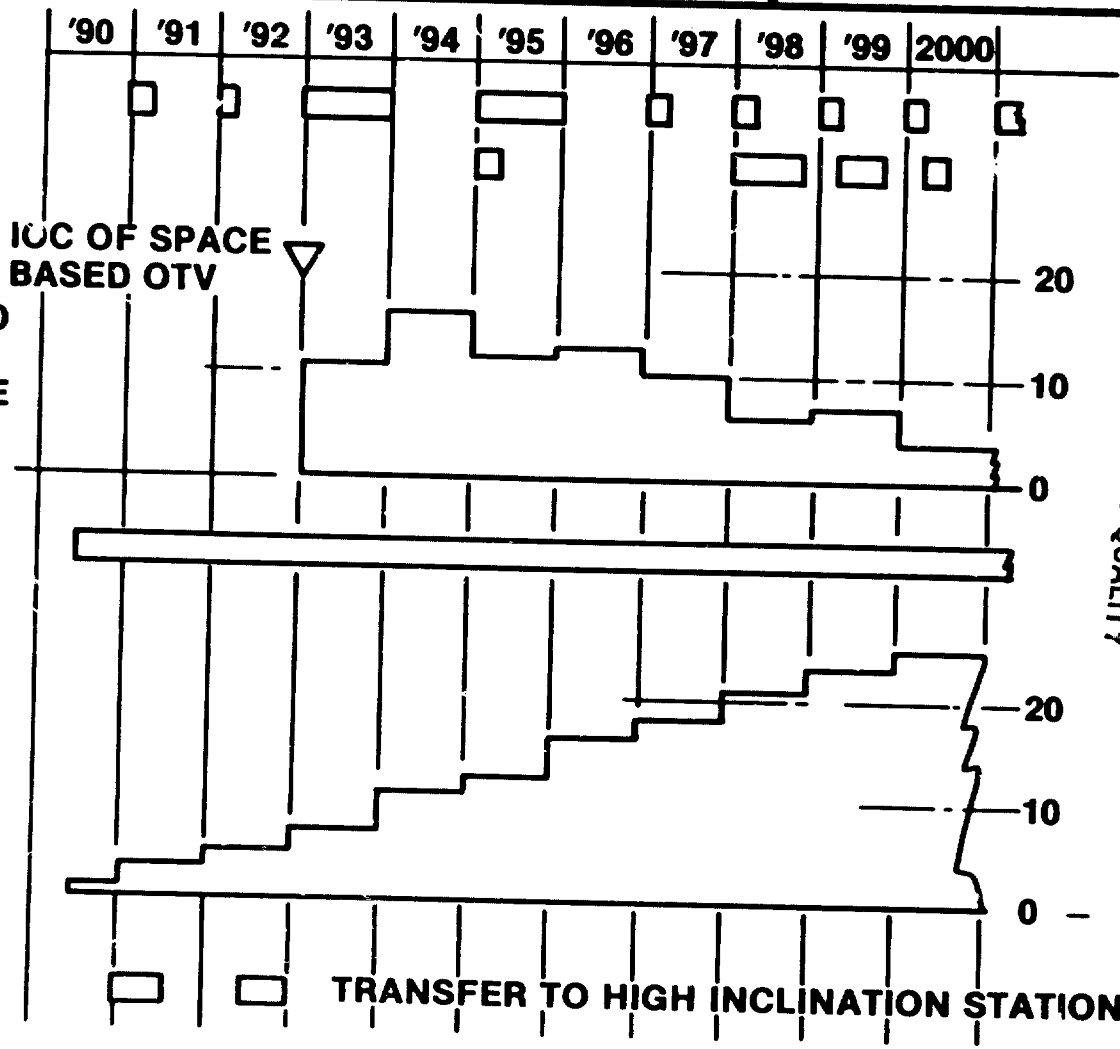
The commercial R&D is essentially done on-board the Station and the "baseline" concept is for production to be done on free flying platforms.

SPACE STATION

COMMERCIAL ACTIVITIES – AT 28.5° BASELINE MISSION MODEL

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL

- COMM
  - COMPONENT R&D
  - LARGE ANT. DEV & QUAL
  - NO. OF COMM SATS. TO GEO
    - FIXED SAT. SERVICE
    - BROADCAST SAT. SERVICE
    - MOBILE SAT. SERVICE
- MATERIALS
  - R&D
  - PROD. UNITS ON LINE
    - HgCdTe
    - THIN FILM GaAs
    - ISOENZYMES
    - BIOLOGICAL
- REMOTE OBSERVATIONS



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SPACE STATION ROLES, SCIENCE & APPLICATION MISSIONS

The Space Station/platform can support Science and Application missions in a 28.5 deg inclination orbit for R&D in an internally mounted pressurized lab and externally mounted platform. This same 28.5 deg Space Station can also provide transportation of science payloads to GEO and serve to launch missions beyond (i.e., planetary). Instruments that require celestial viewing and those that need to observe the earth near the equator can also be mounted on this platform.

Externally mounted earth resources and meteorological payloads that are intended to view the whole earth are mounted on a polar inclination platform. This same platform can also support solar viewing instruments plus celestial viewing that requires high inclination.

Benefits from Space Station for Science and Application missions include the capability to support instruments for long-duration, manned intervention and lower operational costs. The service, maintenance and refurbishment of instruments attached to the Space Station and free flyers improve data collection capability while reducing costs.

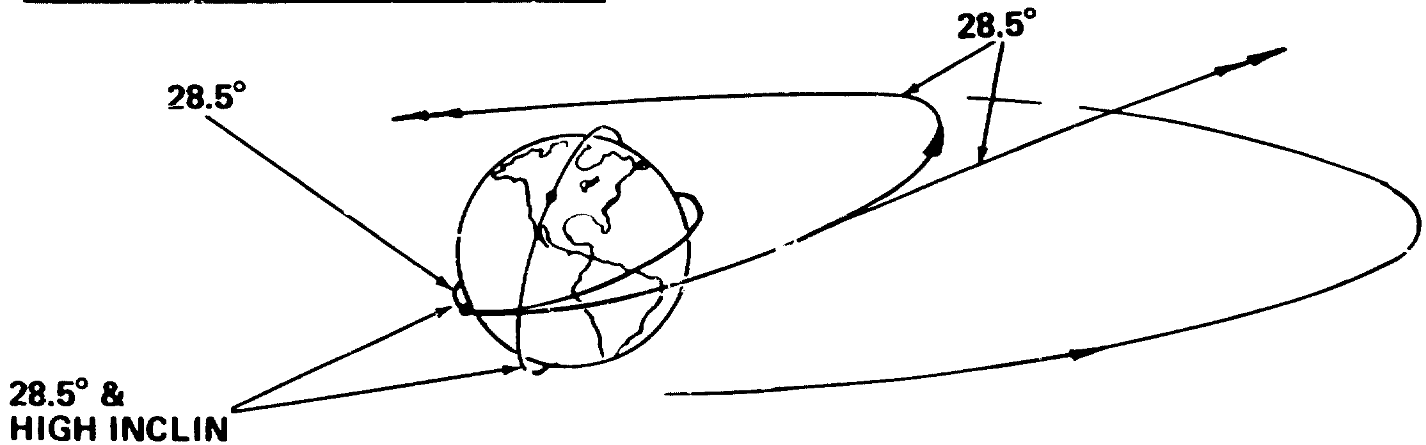
SPACE STATION

SPACE STATION ROLES, SCIENCE & APPLICATION MISSIONS

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL

- R&D – ALL CATEGORIES: MANNED, LONG DURATION SPACE TEST FACILITY

- VEHICLES TO GEO & BEYOND
  – LOW COST TRANSPORT



- TRANSFER CURRENT SORTIE MISSIONS – LONGER DURATION/LOWER TRANSPORT COSTS TO SPACE STATION
- SERVICE LEO FREE FLYERS – LOWER SERVICE & RECONFIGURATION COSTS FROM SPACE STATION
- LOCATE FUTURE SCIENCE MISSIONS – MANNED, LONG DURATION, LOW SUPPORT COSTS WITH RESPECT TO SPACE STATION

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R-004,362.

SCIENCE & APPLICATIONS ACTIVITIES AT 28.5 DEG, BASELINE MISSION MODEL

The 28.5 deg Space Station Baseline Science and Applications missions are shown opposite. Four mission functional groups are shown: internal laboratories; externally mounted instruments; co-orbiting free flyers; and planetary missions. Material science activities commence in 1991 and include investigations of fundamental material properties and processes. Life sciences require humans in space for extended time periods commencing with the monitoring and physiological measurement of the onboard crew and later, laboratory experiments with animals and plants. The global environment experiments start in 1993 and will model the large scale circulation of the earth's atmosphere in hemispherical geometry.

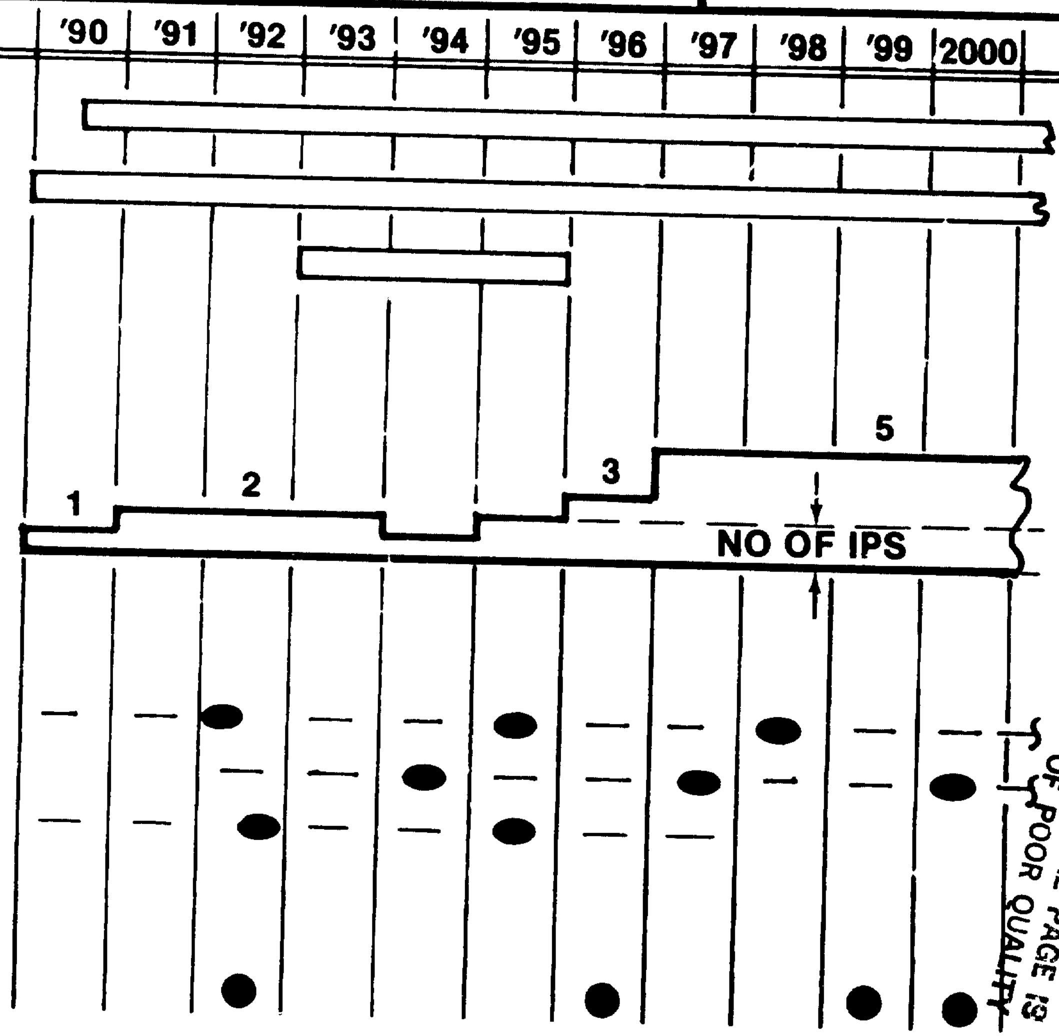
Most externally mounted payloads consist of telescopes that are celestial pointing. The tropical meteorological payload, in contrast, looks at earth to observe weather phenomena in the equatorial region. Because the Space Station will be gravity-gradient oriented, means of accurately pointing the telescopes must be provided, such as the Europeon instrument pointing system (IPS).

Co-orbiting satellites that could benefit from servicing and maintenance are retrieved and serviced at the Space Station on a periodic basis. Servicing events for three free flyers (ST, GRO and AXAF) are shown.

Planetary missions could be supported by the Space Station by mating upper propulsion stages to the instrument payload, then deploying them at the appropriate time.

SCIENCE & APPLICATIONS ACTIVITIES AT 28.5° BASELINE MISSION MODEL

- ▷ INTERNAL LAB
  - • MATERIALS SCIENCE
  - • LIFE SCIENCE
  - • GLOBAL ENVIRON
- ▷ EXT MOUNTED
  - • CELESTIAL PAYLOADS
    - - SIRTF
    - - STARLAB
    - - LAMAR
    - - IR SPECTROSCOPY
- ▷ CLOSE-BY FREE FLYERS
  - • SERVICE EVENTS
    - - ST
    - - AX AF
    - - GRO
- ▷ PLANETARY, ETC – DEPARTURES



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SCIENCE & APPLICATION ACTIVITIES AT POLAR ORBIT

Many of the externally mounted payloads on the polar orbit platform were originally conceived as free flyers. The majority of these payloads are earth viewing and benefit from being able to scan the entire earth surface. The Initial Platform contains four science payloads at one time that increases to 11 in the year 2000. Two free flyers both involved in meteorological measurements, can be serviced from the Polar Orbit Platform.

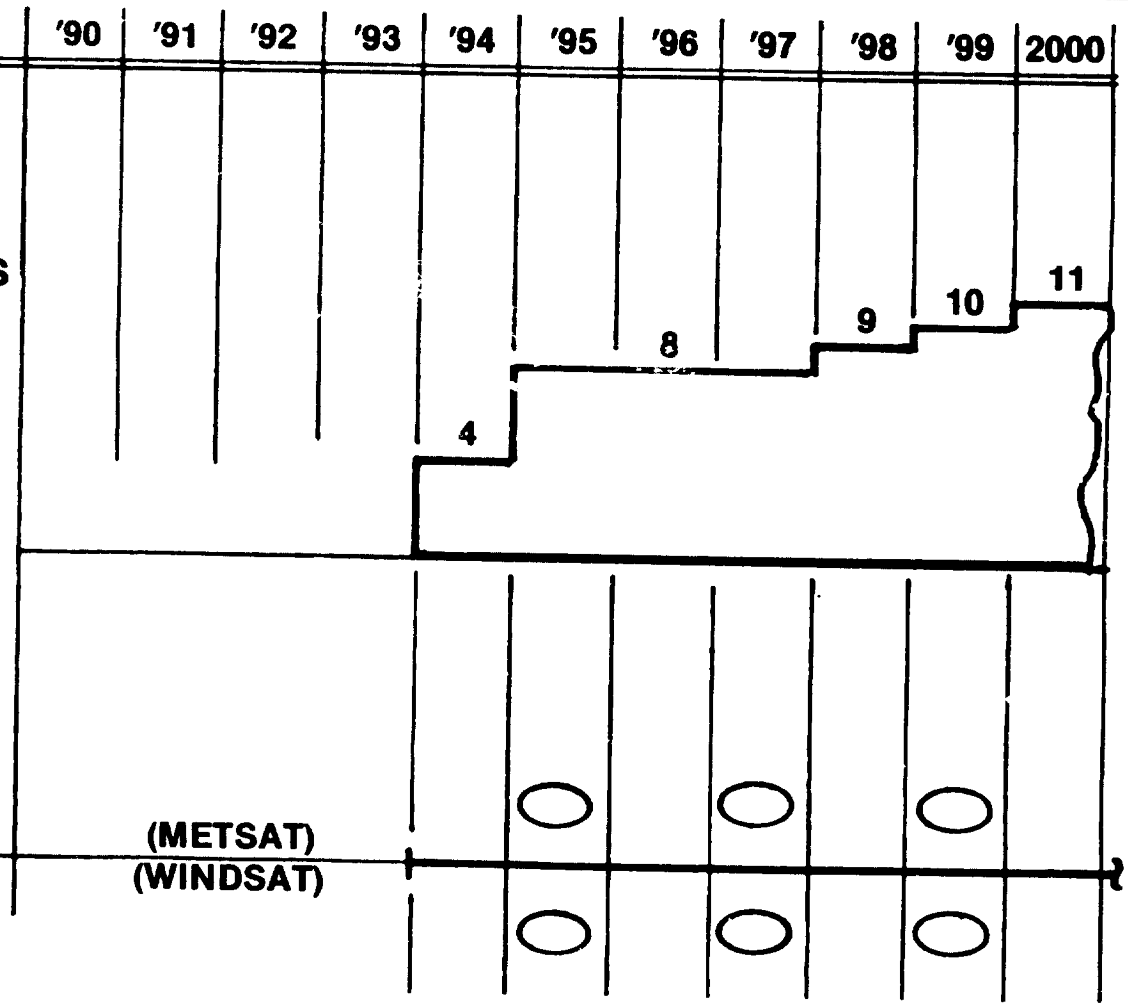
SPACE STATION

SCIENCE & APPLICATIONS ACTIVITIES AT 97°, BASELINE MISSION MODEL

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL

▷ EXTERNALLY MOUNTED PAYLOADS
- VBLI
- HEAVY NUCLEI EXPLORER
- SOLAR TERRESTRIAL OBS
- RENEWABLE RESOURCES
- ADVANCED SOLAR OBS
- GEOLOGY PAYLOAD
- PLUS II OTHERS

▷ CLOSE-BY FREE FLYER, SERVICE EVENTS



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R-004,362.

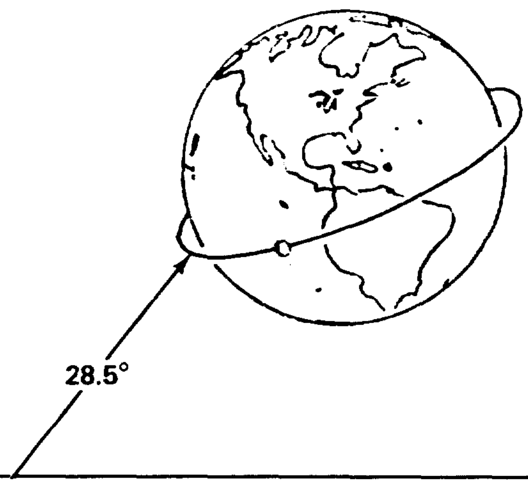
SPACE STATION ROLES, TECHNOLOGY DEVELOPMENT MISSIONS

Space technology development encompasses a variety of R&D subjects including those for the assessment and development of the Space Station and related operations. All of the disciplines and working areas are listed on the facing page.

Technology development is not generally directed toward a specific product or service, but the distinction between space technology development and other R&D is rather subjective. For exampie, commercial communication R&D might be directed toward better land service, but the results might benefit civil or military space applications. A number of technology areas, however, seem clearly related to many applications and are therefore usually funded by the Government. (e.g. propulsion, life support, electrical power generation and system operations).

The Space Station permits a manned, interactive role over a long duration and offers an obvious contribution to all R&D activities. The great majority of space technology missions require no particular orbit inclination or altitude. A 28.5 deg low-earth orbit is preferred because of lowest STS costs.

SPACE STATION ROLES, TECHNOLOGY DEVELOPMENT MISSIONS



- 28.5° PREFERRED FOR MOST R&D MISSIONS
- CIVIL & MILITARY

• COMMUNICATION • CRYOGENICS • DATA MANAGEMENT • ENVIRONMENT CONTROL & LIFE SUPPORT • HUMAN CAPABILITIES • MATERIALS • NATURAL & INDUCED ENVIRONMENT • NAVIGATION, GUIDANCE, CONTROL	• OPTICS • POWER & ENERGY STORAGE • PROPULSION • SENSORS • SYSTEM OPERATIONS • STRUCTURES & MECHANISMS • THERMAL CONTROL	• LOWEST COST TRANSPORT TO: – MANNED – LONG DURATION – SPACE TEST FACILITY

V83-0165-437(T)

R-004,362.

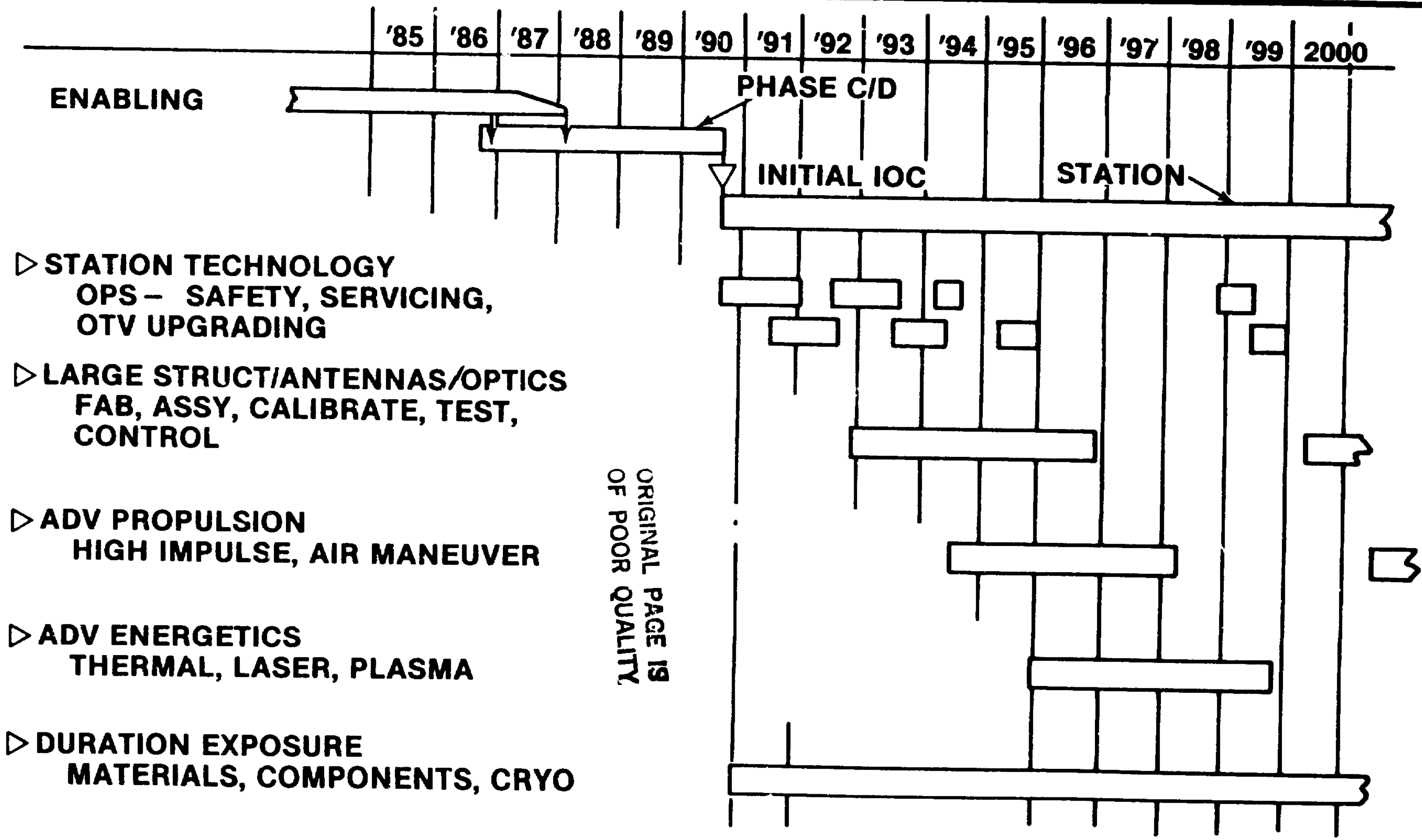
TECHNOLOGY DEVELOPMENT ACTIVITIES AT 28.5 DEG INCLINATION

The key technology development activities projected for the Space Station are shown. The development activities required for the Station itself will have been completed but operations development and upgrading will continue intermittantly through the 90's. Some technical development activities will have been completed with the orbiter, spacelab or free flyers before the Space Station becomes operational, and some may be accomplished with similar spacecraft in the 90s. The activities selected are particulary suited to the Space Station attributes (large structures & long duration exposure) or advanced programs (propulsion, energetics).

SPACE STATION

TECHNOLOGY DEVELOPMENT ACTIVITIES IN-ORBIT AT 28.5° INCLIN

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL



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DoD ACTIVITIES

DoD activities involve R&D, deployment of satellites to GEO using OTVs, assembly and servicing of large system and servicing "current" satellites in situ or at the Space Station. These activities require three Space Station inclinations as indicated on the facing page. Activities at 28.5 deg inclination which include R&D missions and GEO deployments have been included in the Baseline Mission Model.

Large military systems at 57 deg inclination are possible but probably will occur after the year 2000. If a 57 deg Space Station is justified for these large systems, it could be used to service "current" conventional satellites in this orbit.

The major activity of a 97 deg station is to support the servicing of "current" conventional satellites.

SPACE STATION

DoD ACTIVITIES

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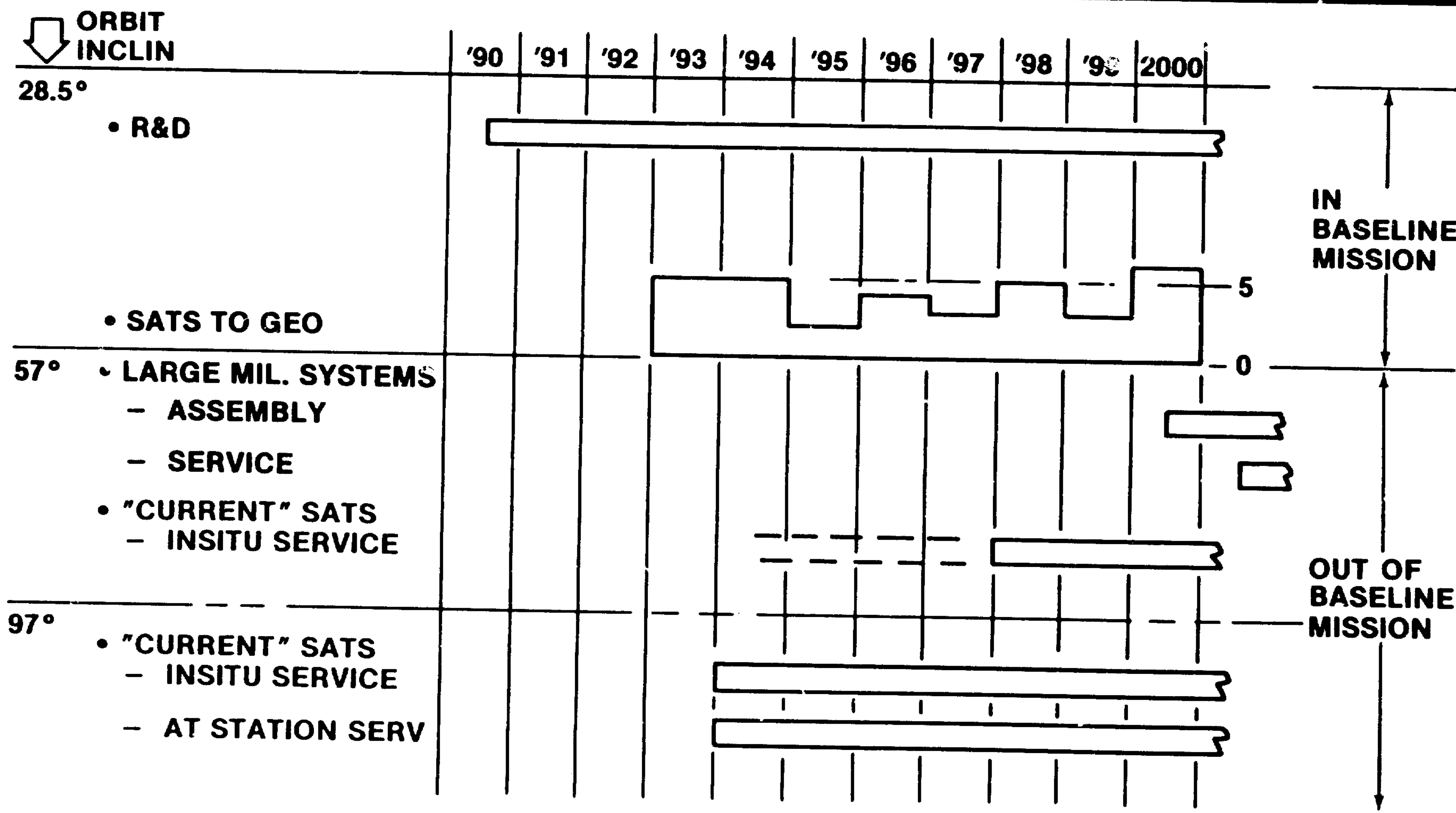
GENERAL ELECTRIC
COMSAT GENERAL



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SPACE STATION AT 28.5, 57 DEG AND POLAR INCLINATIONS

A summary of the preferred Space Station orbital inclinations to support the mission operational objectives of the varied military and non-military (civil) missions/payloads is contained on the facing page. All missions/payloads that either have no preferred orbital characteristics, or whose destination is geosynchronous orbit or beyond were placed in a 28.5 deg inclination orbit, since this results in the lowest transportation cost to orbit.

A polar orbit provides the best solar and terrestrial coverage for all civil missions. Some Science and Application missions would perform satisfactorily in a 57 deg inclination orbit, which represents the highest achievable inclination from ETR due to Space Shuttle launch constraints. The European community favors a 57 deg inclination orbit for ease of communication witn the ground.

When all the missions/payloads that prefer orbital inclinations greater than 28.5 deg are summed, the total projected traffic cannot justify a permanent presence at more than one inclination. Since many payloads require polar orbit to satisfy their mission objectives, all higher inclination civil missions were integrated with the polar missions in the baseline mission model. Consequently, the baseline mission model identified candidate Space Station missions at two inclinations, 28.5 deg and polar orbit.

SPACE STATION

ACTIVITIES RELATED TO LEO SPACE STATION AT 28.5°, 57° & POLAR INCLINATIONS

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL

ORBIT INCLIN	28.5°	57°	POLAR
STS FLTS/YR	11	1+	2
COST TO LEO $/KG	2600	3380	6750
EARTH COVERAGE—%	48	86	100
LEO MISSIONS	○★ R&D ○★ MATL PROCESS ○ ASTRONOMY ○ LIFE SCIENCES	★ NAVIGATION ★ SURVEILLANCE ○ EUROPEAN S/C	★ WEATHER ○ RESOURCE OBS ★ SURVEILLANCE ○ SOLAR OBS
GEO MISSIONS & BEYOND	○★ COMMUNICATION ○★ WEATHER ★ SURVEILLANCE ○ PLANETARY		

★ MILITARY USERS
○ NON-MILITARY USERS

INITIAL SPACE STATION AT 28.5°
- LOWEST COST TO LEO & BEYOND

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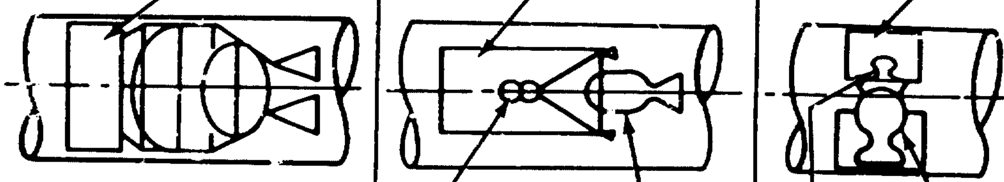
THREE EXPENDABLE SHUTTLE-BASED METHODS FOR P.L. TRANSFER TO GEO

These expendable OTVs are typical of those expected to be available in the early 90s. They are ground-based and offer an alternative to the development of space-based OTVs in the early years. Their payload to GEO capability is significantly less than the space-based OTVs.

THREE EXPENDABLE SHUTTLE BASED METHODS FOR A PL TRANSFER TO GEO

	CENTAUR G	INTELSAT VI TYPE	PAM-D
MAX PAYLOAD MASS TO GEO (KG)	6000	3000	600
APOGEE KICK	CENTAUR	STORABLE PROP INTEG WITH PL	SOLID ROCKET
PERIGEE KICK	CENTAUR	SRM-1 (IUS DERIVED)	STAR-48



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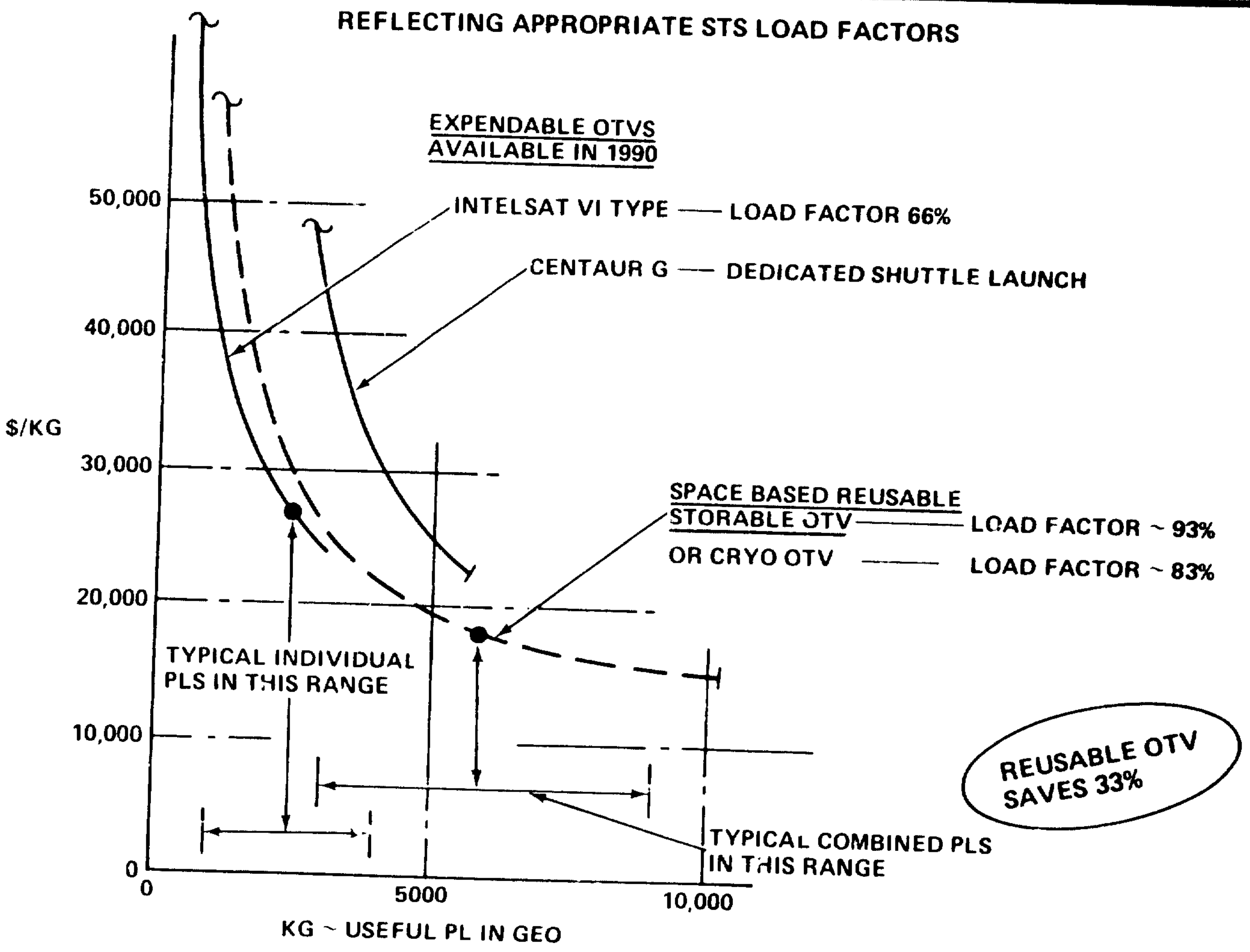
COST OF GROUND-TO-GEO TRANSPORT

The civil and DoD traffic to GEO in terms of numbers of payloads and weight of payloads was derived for the 1990s. To satisfy this requirement, three types of ground-based OTVs (PAM-D, Intelsat V1 type and Centaur G) and two types of space-based OTVs (storable OTV with AKS and cryo OTV with AKS) were studied. A comparison of their performance in $/kg assuming a Shuttle load factor of 100% was determined. Shuttle manifesting using each of these stages showed marked differences in efficiency for each upper stage. Clearly a spacebased reusable upper stage is the most cost-effective form of transportation provided the payload mass-to-GEO is greater than 4000 kg per OTV flight. Typically, combined payloads run in the range from 3500 to 9000 kg. Thus, by combining payloads on one OTV flight, an efficiency of scale is obtained in addition to the above mentioned STS manifesting benefits.

SPACE STATION

COST ($ '84) OF GROUND TO GEO TRANSPORT

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL



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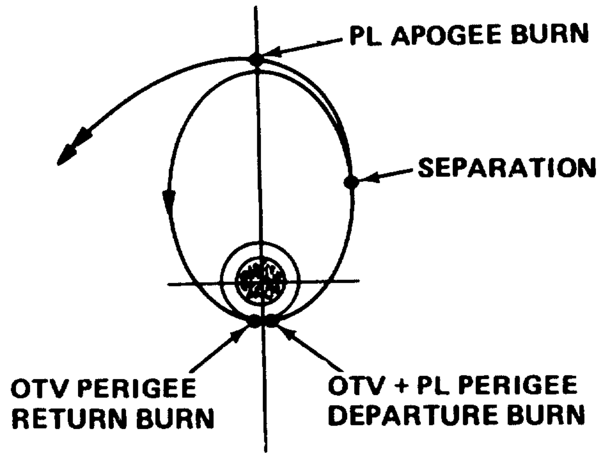
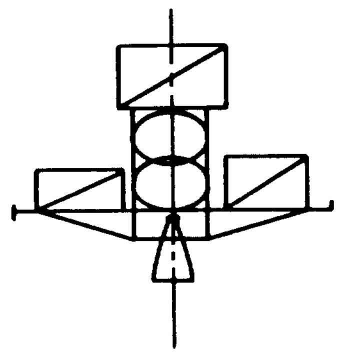
REUSABLE SPACE-BASED OTV

The reusable space-based OTV is an efficient means of launching a spacecraft into its operational trajectory. The chart on the facing page shows the OTV inserting its attached payload spacecraft into a transfer orbit, separating from the payload, then returning to perigee and circularizing for subsequent Space Station berthing. Meanwhile, the spacecraft coasts to apogee and its attached propulsion is used for the circularization burn, placing the spacecraft into its operational orbit. The OTV is versatile, as it could deploy three payloads, transfering a total of 20,000 kg into GEO transfer orbit.

REUSABLE SPACE BASED OTV FEATURES

EFFICIENT FLIGHT MODE	• OVERSIZED RCS TANKS IN PAYLOAD CARRY APOGEE IMPULSE ~ PROVIDING SYNERGISTIC TWO-STAGE DEPLOYMENT TO GEO
LOW OPERATING COST	• REUSABLE • PROPULSION UNIT REMAINS ON SPACE STATION ~ ONLY PROPELLANT IS LAUNCHED
COST EFFECTIVE OTV MANIFESTING	• UP TO THREE PAYLOADS READILY ASSEMBLED TO OTV AT SPACE STATION
PERFORMANCE	• 20,000 KG INTO GEO TRANSFER ORBIT





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CANDIDATE SPACE STATION-BASED REUSABLE OTVs

These are two candidates space-based OTVs which have the same general features. In each case, the propulsion unit is space-based but the tanks are ground filled and transferred to orbit by Shuttle. The storable OTV has lower performance but is a shorter length tank. Cost tradeoffs show that, over the course of the program, the launch costs saved by the shorter tank offset the costs savings given by the cryos superior performance.

Up to three payloads can be transferred to GEO by either vehicle.

SPACE STATION

CANDIDATE SPACE STATION BASED REUSABLE OTV'S

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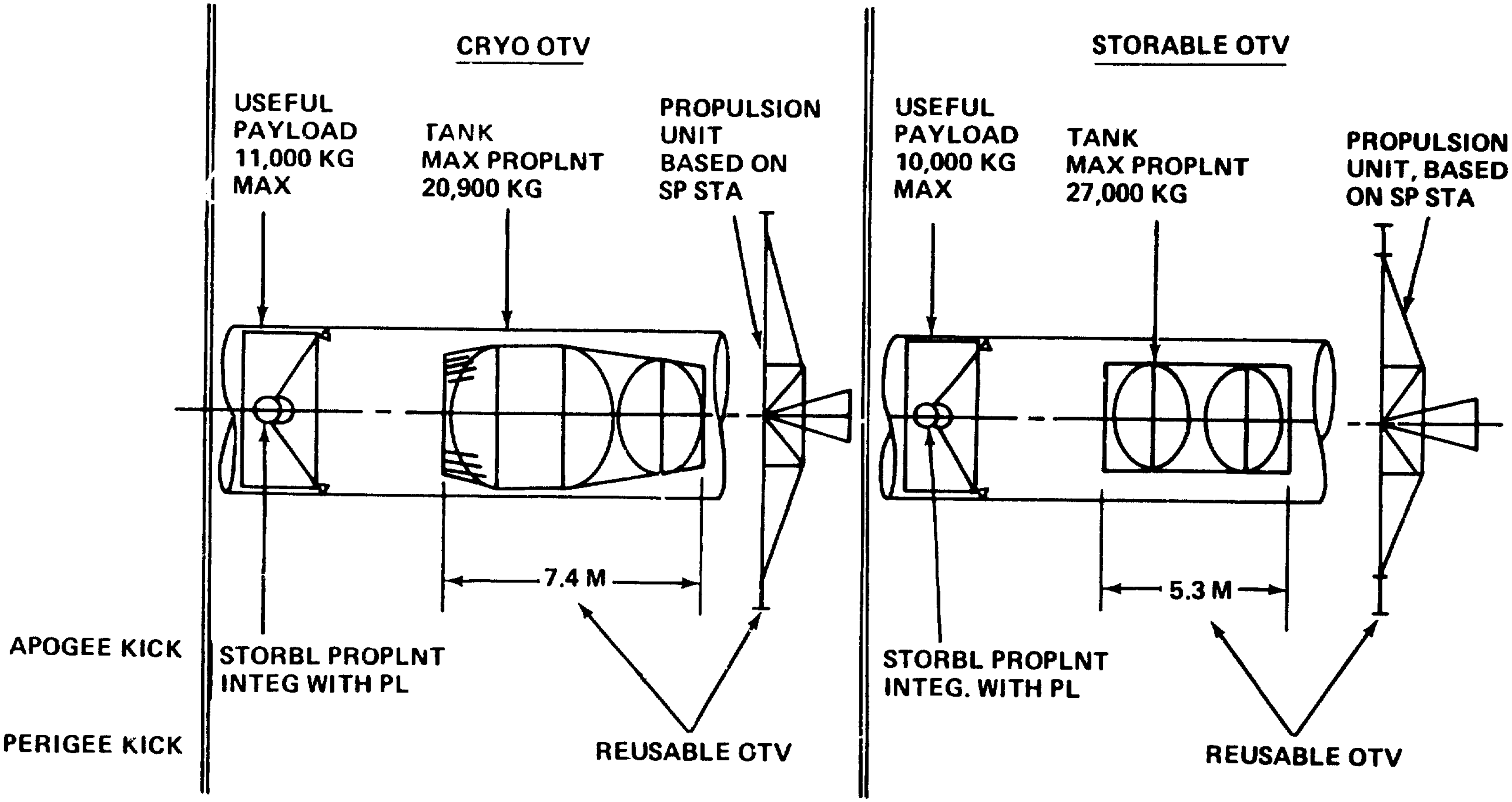
COMSAT GENERAL



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COST FOR TRANSPORT OF SATELLITES GROUND-TO-GEO

The figure on the facing page compares the recurring cost for GEO transport using the most cost-efficient ground-based mode, vs the space-based mode, over a typical four-year interval. If both military and civil traffic is considered, a $318M/year savings can be obtained by space basing. However, against this savings the cost of developing both the OTV and its transport harbor must be amortized.

SPACE STATION

COST FOR TRANSPORT OF SATELLITES, GROUND TO GEO

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL

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- EXPENDABLE VS. REUSABLE SPACE BASED OTVS
  - (ALL COSTS IN '84 $ M)

	'93	'94	'95	'96	AVG ANNUAL SAVING
▹DoD TRAFFIC					
EXPENDABLE OTVS	424	258	104	273	
REUSABLE, SPACE BASED	254	184	82	191	
SAVING	170	74	22	82	87
▹CIVIL TRAFFIC					
EXPENDABLE OTVS	594	822	627	690	
REUSABLE SPACE BASED	383	544	422	459	
SAVING	211	278	205	231	231

COMBINED AVERAGE SAVINGS $ 318 M/YR

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PAYBACK PERIOD FOR NEW OTV & TRANSPORT HARBOR

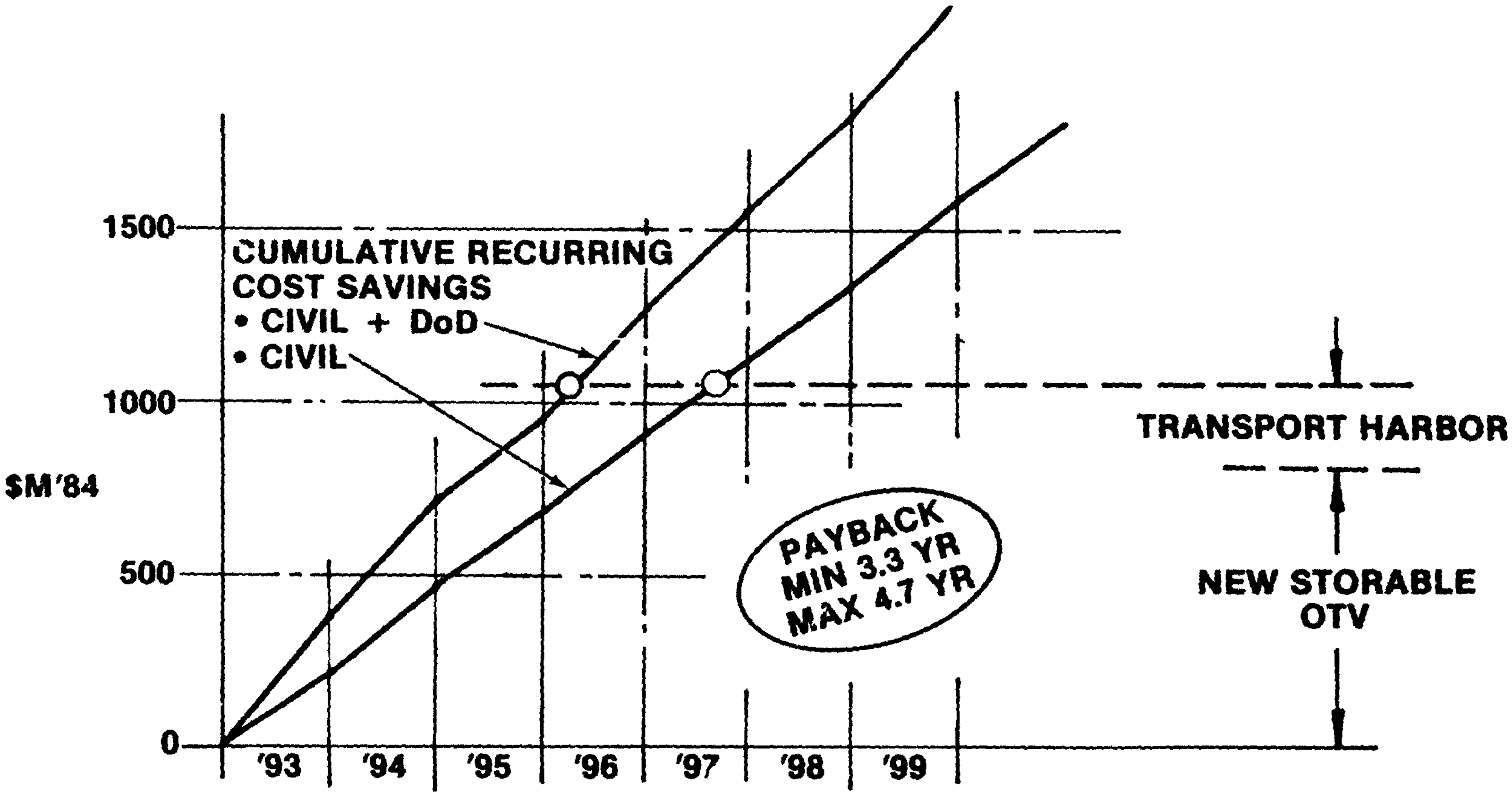
When the recurring cost savings are compared with the program costs for both the transport harbor and the OTV, a payback period of from three to five years results with currently projected traffic rates (approximately eight OTV flights to GEO per year). This would be cut by 50% with twice the projected rate. At approximately three-times the traffic rate, the transport harbor must be enlarged to handle the increased traffic. Less propellant is needed with a cryo OTV; however, a storable OTV permits higher Shuttle load factors, lower front end costs and departure on demand.

This study indicated that a reusable OTV is in fact a cost-effective mode of operation and the transport harbor forms an integral part of the evolutionary 28.5 deg Space Station.

SPACE STATION

PAY BACK PERIOD FOR NEW OTV & TRANSPORT HARBOR

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL



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28.5 DEG INCLINATION SPACE STATION INTEGRATED REQUIREMENTS

Integrated requirements for the 28.5 deg Space Station are summarized opposite. The number of Shuttle flights, for example are subdivided into civil missions, military traffic to GEO and the military R&D missions. Expendable upper stages are used prior to OTV IOC (1993).

The average electrical power required for mission activities on the 28.5 deg Space Station are also shown. The average electrical power requirements for the military R&D missions (maximum of 3100 kwh/yr) has an almost negligible impact. If the Space Station is required to provide power for an industrial park, the power requirement increase dramatically.

The integrated crew requirements show that the military R&D missions require a more rapid buildup than would be required for the civil missions alone. The integrated (civil plus military) requirements shows the crew requirements building up to a total of 10 starting in 1995. A crew size of nine would probably suffice by adjusting total integrated crew work schedules.

SPACE STATION

28.5° SPACE STATION INTEGRATED REQUIREMENTS

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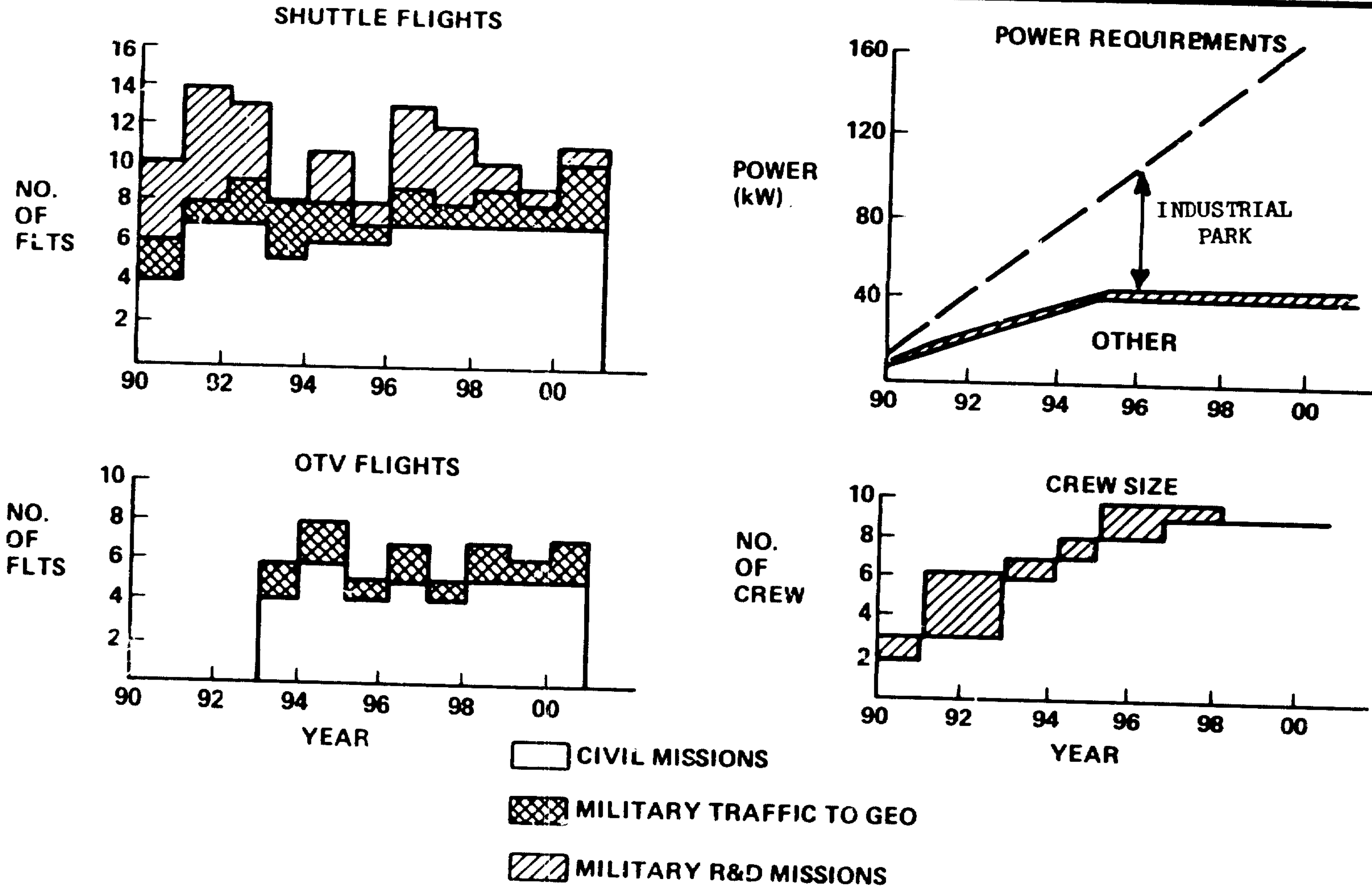
GENERAL ELECTRIC
COMSAT GENERAL



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FIVE REQUIRED ATTRIBUTES

Based on an evaluation of the wide and varied range of Space Station mission applications, it is evident that Space Station architectural development should key on the five attributes/roles shown.

1) The space test facility and range provide the unique opportunity to conduct technology development and proof-of-concept in space with manned interaction in the development process. A shirt sleeve environment provides ideal conditions for an industrial research facility, to conduct materials research and development relevant to commercial products and services, and a Life Sciences Lab; 2) A Transport Harbor has great utility and an ever-expanding role. Initially, it provides Shuttle support and repair in case of Shuttle malfunction. For upper stage operations, the Transport Harbor would first support small "proximity operations" vehicles and later storable propellant upper stage vehicles such as the Teleoperator Maneuverable Systems (TMS). Finally, a reusable OTV would become operational providing lower cost transportation to GEO; 3) Satellite servicing and assembly is another major area for high payoff with the Space Station. Satellite servicing pays off particularly for large observatory satellites; 4) The fourth major area for high payoff is an observatory attached to the Space Station with appropriate vibration isolation so that the delicate instrumentation and telescopes may be pointed earthward or toward the heavens with reasonably high accuracy; and 5) Materials processing in space offers both technical and economic advantages over earth-based manufacturing procedures. Not only are higher quality products produced in the space environment, but also a significantly higher product yield results when processing materials in a near-zero-gravity field.

SPACE STATION

FIVE REQUIRED ATTRIBUTES

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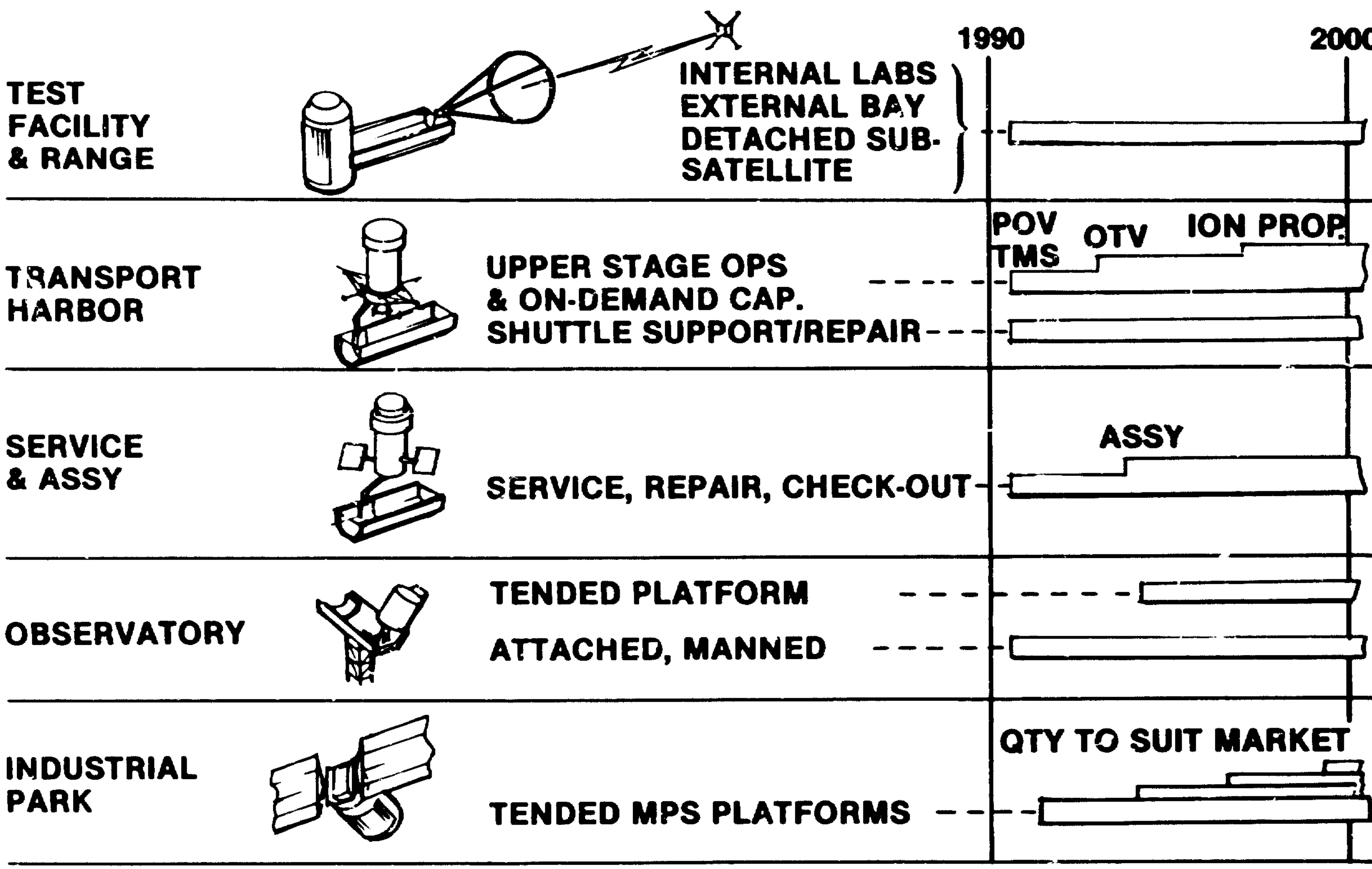
COMSAT GENERAL



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SPACE STATION OPERATIONAL REQUIREMENTS & FUNCTIONS

An example of Space Station operational requirements and functions is shown opposite for the transportation Harbor. Highlighted are the user interfaces in terms of systems support, IVA and EVA capability, mobile units needed and ground control. The number of pieces of equipment needed and structural, power and data capability are listed. The OTV operational phases that involve the user are mating the payload (satellite) to the OTV, checkout, transportation to operational orbit, and separation of th payload in preparation for performing its operational role. Note that the equipment and facilities can nominally support 12 flights per year.

Similar summary sheets were prepared for the other Space Station primary functions; namely test facility and range, satellite servicing/assembly, observatory and industrial park.

SPACE STATION

SPACE STATION OPERATIONAL REQUIREMENTS & FUNCTIONS

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL

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INDUSTRIAL PARK
OBSERVATORY
SATELLITE SERVICING/ASSEMBLY
TEST FACILITY & RANGE
TRANSPORT HARBOR

OPERATION NEEDS	QUANTITIES		OTV OPS PHASES				
	INITIAL	EVOLVED	PYLD MATE C/O & SEP-ARATION	PYLD TRANSP	OTV RETURN /BERTH	OTV TURN-AROUND	
SYSTEMS SUPPORT							12 FLTS/YR NOMINAL CAPACITY
• WORK BAY LENGTH	6m	9m	•		•	•	
• STORAGE LENGTH	3m	9m	•			•	
• POWER	4 kW	6 kW	•			•	
• DATA	140 KOPS	200 KOPS	•			•	
IVA CAPABILITY							
• CONTROL STA	1	1	•		•	•	
• RMS/HPA	1 EA	2 EA	•		•	•	
• DEXTEROUS MANIP	–	1	•			•	
EVA CAPABILTIY							
• MMU	–	2	BACKUP				
• OCP & MFR	1	2	•			•	
• TOOLS	1 SET	1 SET	•			•	
MOBILE UNITS							USER INTERFACE
• POV & TMS	1 EA	1 EA					
• OTV	–	1	•	•	•		
GROUND CONTROL				•	•	•	

V83-165-933(T)

R-004,362.

FINAL SUMMARY BRIEFING AGENDA

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- INTRODUCTION & CONCLUSIONS
- REQUIREMENTS
- **ARCHITECTURE & TECHNOLOGY**
- COSTS & BENEFITS
- SUMMARY RECOMMENDATIONS

V83-0165-727(T)

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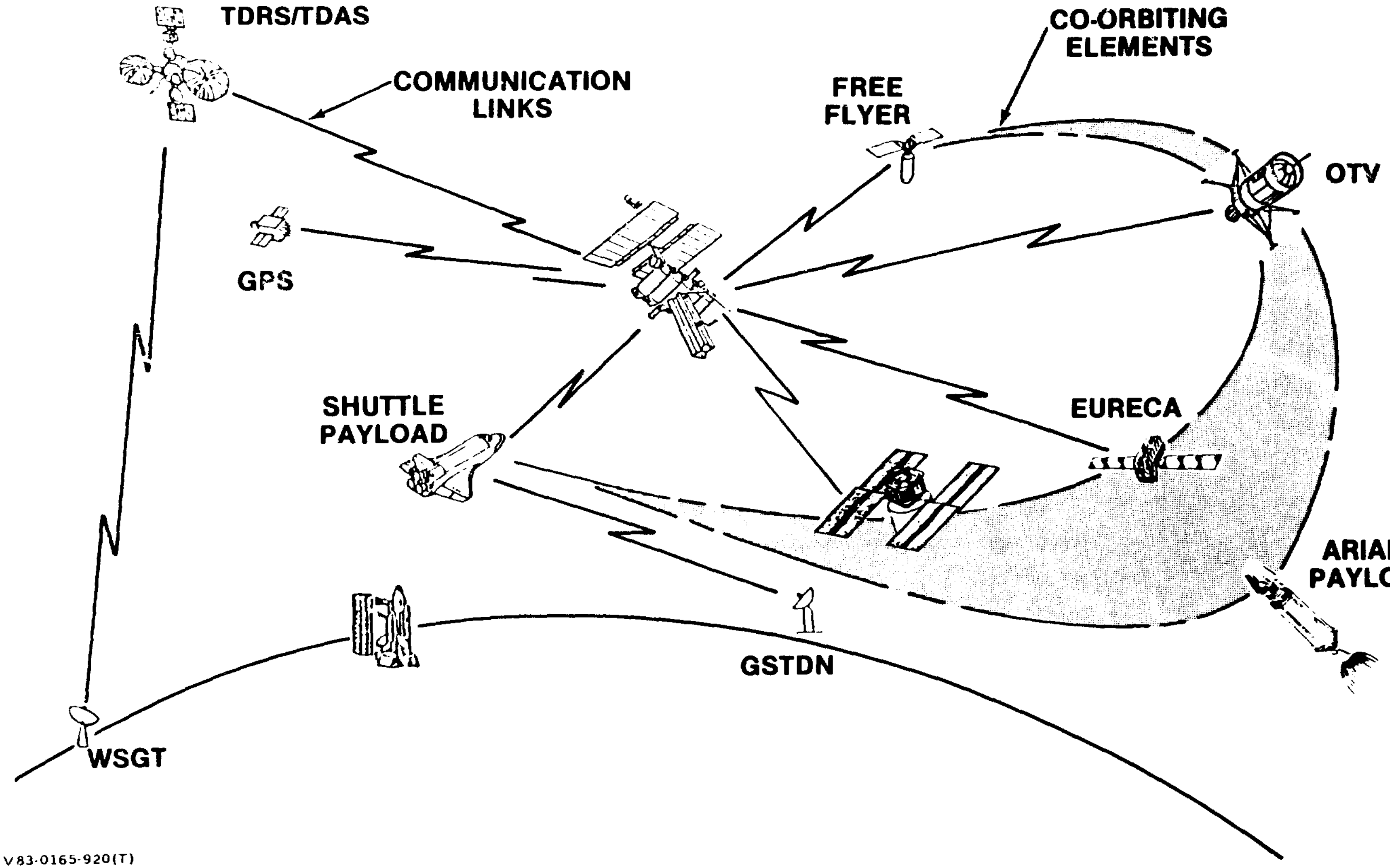
SPACE STATION INFRASTRUCTURE

The Space Station infrastructure consists of that space community within a sphere defined by the earth as center and of GEO radius and beyond. Within this spherical community the Space Station is an operational node with interconnecting arteries to terrestrial and space-based terminals. The Space Station facility, in addition to accommodating a diversity of spacecraft, performs a variety of missions support. Its complementary operational interfaces with terrestrial (GSTDN, shuttle, other) and space (TDRSS, GPS) based facilities provides for increased effectiveness in the exploration and productive use of space.

Space Station operational services to the other elements of the infrastructure include such activities as servicing, communications (command, data reception), stationkeeping and mission operation control. These services will be on a continuous, periodic or intermittent basis, dependent on each spacecraft's requirements. The tended industrial platforms, co-orbiting spacecraft and attached payloads can be accommodated more frequently and continuously as compared to ground-based facilities. Other satellites requiring servicing can be attended to as the need arises. In addition, the preparation and higher orbit insertion of satellites will be provided by the OTV in conjunction with Space Station operations. Planetary spacecraft may also have their journey initiated from the Space Station.

SPACE STATION INFRASTRUCTURE



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MOBILE ELEMENTS & THEIR TECHNOLOGY

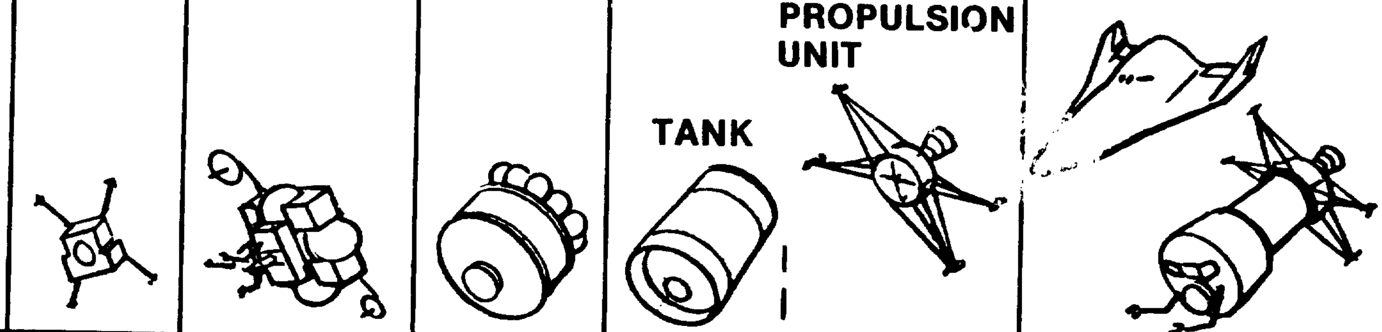
To perform its missions, the Space Station system requires some elements that are not permanently attached to it. Mobile elements identified so far are shown here. The space-based POV and TMS fetch and carry free flyers to the Station. A ground-based logistics module contains resupplies for crew and equipment. The space-based OTV is used primarily, to take payloads to GEO and for planetary missions. Beyond the missions of immediate concern to this study, potential requirements include such a capability as manned OTV. This could be an "all propulsive" or an aeromaneuvering vehicle. The probable IOC is given for each element, together with its technology development requirements.

It is vital to program costs that the mass of each element be kept as low as possible. In the case of POV, TMS and OTV, their refuelling propellant must be transported from the ground and the logistics module is ground-based. Therefore, each demands shuttle payload volume and mass that reflect on transport costs.

SPACE STATION

MOBILE ELEMENTS

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL



	POV	TMS	LOGISTIC MODULE	STORABLE OTV	MANNED CAPSULES
IOC	'85	'86	'90	'93	'98
AUTONOMOUS FLT		✓		✓	
BERTHING	REMOTE	REMOTE			MANNED
TAMING UNCO-OPS	✓	✓			
MANIPULATORS		✓			
PROPULSION PERF				IMPORTANT	
AIRMANEUVERING					✓
MAINTAINED IN ORBIT	✓	✓		✓	✓

LOW WEIGHT VITAL FOR ALL MOBILE HARDWARE

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BASIC BUILDING BLOCKS

In arriving at a preferred system architectural configuration, the issue of commonality plays an important role. In particular, the impact on costs for using common elements as replicated items is a high level discriminator. Our baseline system comprises a manned Station plus industrial park free flyers in 28.5 deg inclination and an observation platform in polar orbit. This chart shows four basic building blocks and their replication in the Space Station system facilities.

A core module provides the pressure vessel used on the manned Station for habitation and laboratory modules. The tended industrial platforms use the same core and many of the same subsystem elements. Similarly, the polar platform uses the core module to house subsystems.

The external subsystems pallet, power source and support mast combination is used on all of the system facilities. The size of the array differs, but each array is assembled from identical panels. The mast length differs with each facility, but each is a multiple of standard sections. The subsystems on their common pallet mount are multiples of the same battery, the same cmg, etc.

A surrogate bay is the structure that mounts EVA equipments. In itself, it is a replicated structure for each application. It is used on the manned Station and on the polar platform.

A tower to support observation instruments is used on the manned Station and the polar platform. For most of its length, it uses the same standard sections as the solar array support mast.

BASIC BUILDING BLOCKS

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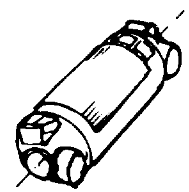
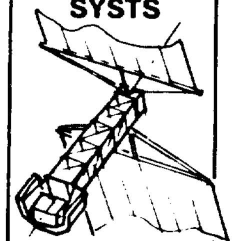
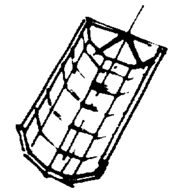
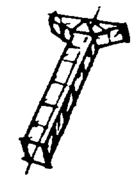
INCLIN		IOC	PRESS. VESSEL CORE	EXT SUB SYSTS	SURROGATE BAY	OBSERV TOWER
						
28.5°	INITIAL STATION	'90	3 CREW HAB	22 kW		
	GROWTH	'91 '93	3 CREW HAB; LAB	PLUS 44 kW		
28.5°	TENDED I:DUST PLATFORM	'92 ON	M.P.S. X4	28 kW X4		
97°	TENDED POLAR PLATFORM	'94	TENDED HAB	14.5 kW		
	GR?WTH	'96		PLUS 14.5 kW		
			10	6	10	2

REPLICATION TO HOLD DOWN COSTS

V83-0165-909(T)

R-004,362.

INITIAL SPACE STATION AT 28.5 DEG

This chart shows the concept for the Initial Space Station that fulfills near-term requirements. Initially, the Station has one pressurized core module which houses three men, necessary subsystems, a life sciences laboratory area and two Extra Vehicular Activity (EVA) command post control/monitor areas. Tunnel extensions provide berthing points for a visiting orbiter.

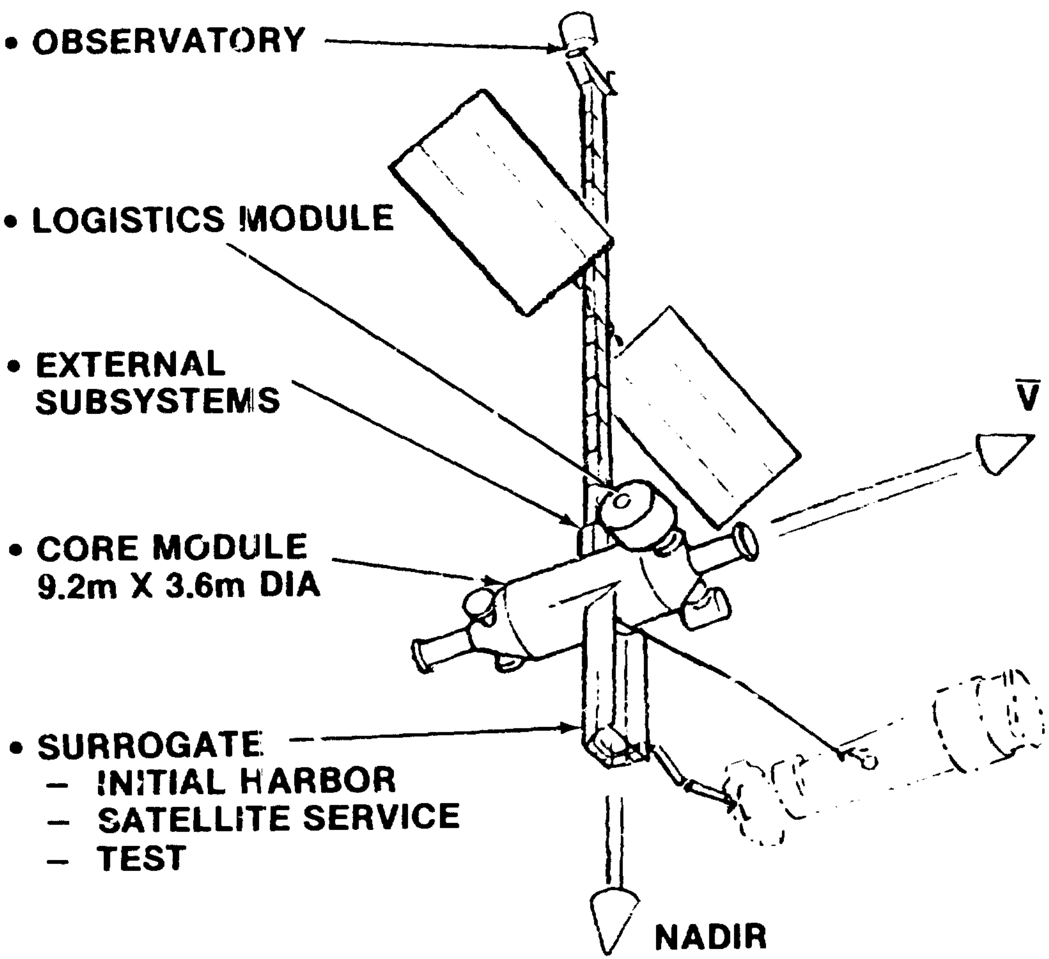
The EVA activity area on this Initial Station has a structure, whose crosssection is a trough which simulates the orbiter's cargo bay. This surrogate, with its equipment, caters to satellite servicing and to space testing, and it is used as the initial transport harbor.

An external subsystems pallet mounts batteries for dark side power, conversion equipment and control moment gyros for attitude control. From this pallet, a mast extends outboard to mount an astrophysics viewing instrument at its tip. This mission requires an unocculted view for 2π steradians, anti-earth. The solar array is located so that it does not interfere with the EVA activities area, orbiter docking or the unloading of payloads. It provides 22 kw of continuous power. A logistics module is berthed to the pressurized module.

SPACE STATION

INITIAL SPACE STATION AT 28.5° INCLIN

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL



- CREW SIZE = 3
- POWER = 22 kW
- MASS = 22,000 kg
- COST = $4.28 B
- TYPICAL MISSIONS
  - ASTRONOMY
  - LIFE SCIENCES
  - POV & TMS TURNAROUND
  - SATELLITE SERVICE
  - R&D

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INITIAL SPACE STATION BUILDUP, FIRST LAUNCH

The building sequence for components carried on the first of two buildup Shuttle launches is shown here. Main orbiter equipments used in assembly are the RMS, the assembly HPA, the OCP mounted to the RMS end effector and carrying an EVA crewman; and an EVA crewman with his MMU is available to assist.

Step 1 used the RMS to deploy the core module and the wrapped-around surrogate structure clear of the orbiter. An EVA crewman extends the habitat tunnels from the module end domes. These tunnels mount berthing rings on their ends.

Step 2 mounts the module to the HPA, then the RMS removes the surrogate structure from around it. An EVA astronaut operates the mechanism which opens the surrogate structure to its full width and attaches necessary cross bracing. The surrogate is transferred to its position against the side of the habitat module and attached. Equipment is installed in the surrogate.

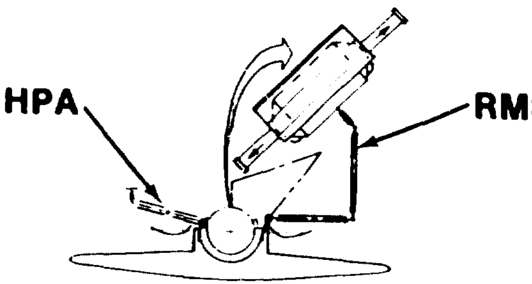
In Step 3, the assembly thus far is rotated 180 deg on the HPA. The RMS removes the external subsystem pallet, with its contents from the payload bay and locates it against the opposite side of the habitat module. The EVA astronaut secures it in place.

Step 4, assembles the solar array support tower and installs the folded solar array wings. The mast is presently conceived as being assembled from five compact folded segments, each of which is carried by a tethered EVA/MMU crewman, attached, then unfolded. Solar array panels are SEPS extensible type and will be transferred and installed by the EVA/MMU crewman, then deployed.

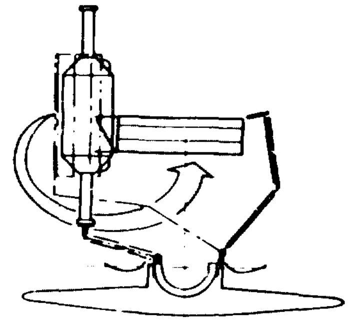
SPACE STATION

INITIAL SPACE STATION BUILDUP — FIRST LAUNCH

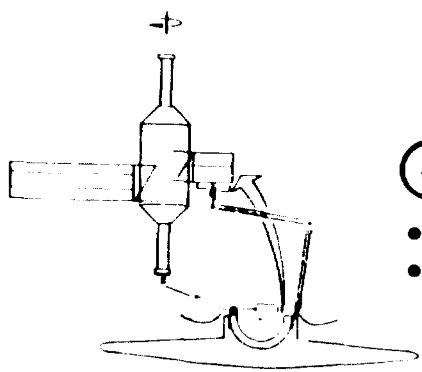
GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL



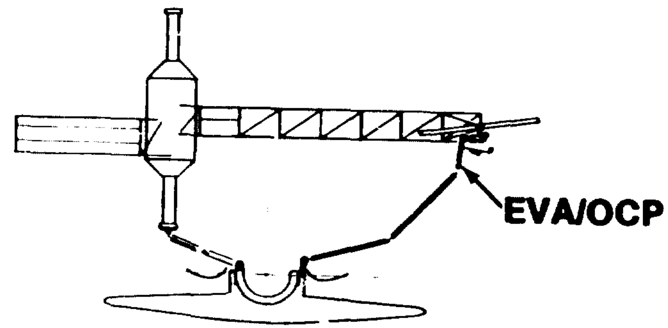
(1)
- DEPLOY CORE MODULE USING RMS
- EXTEND TUNNELS



(2)
- MOUNT ON HPA
- DEPLOY WRAPAROUND SURROGATE
- MOUNT TO MODULE
- INSTALL EQPT



(3)
- ROTATE ASSY 180°
- DEPLOY SUBSYS PALLET & ATTACH TO MODULE



(4)
- ATTACH UNFOLDABLE MAST SEGMENTS (EVA/OCP/RMS)
- ADD SOLAR ARRAY ASSY

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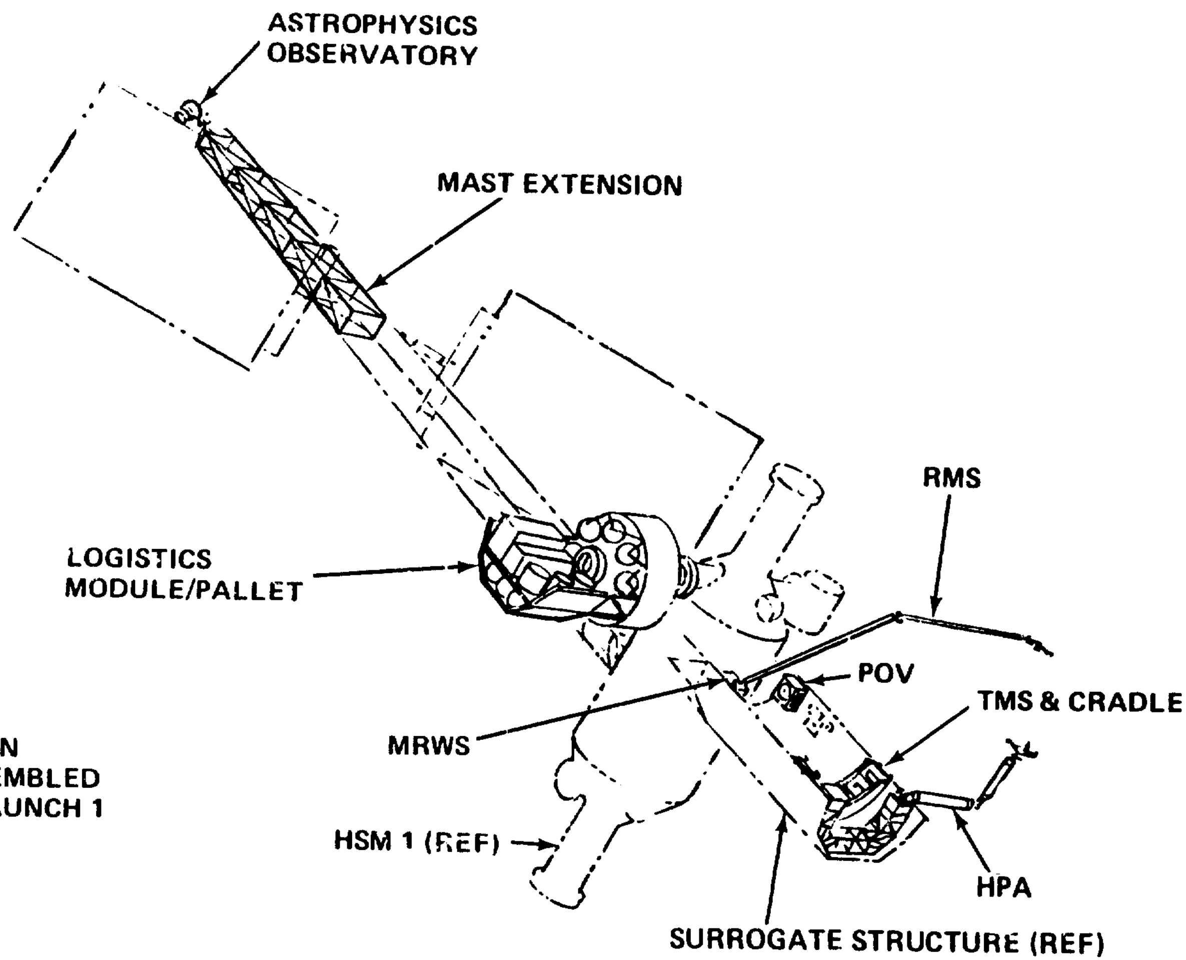
INITIAL SPACE STATION, ASSEMBLY OF LAUNCH NO. 2 COMPONENTS

This chart illustrates the operational location of those Space Station elements that are brought up on the second launch. Items brought up and assembled on the first launch are shown in phantom outline. The POV, MRWS, RMS, HPA and the TMS with its cradle assembly, are removed from the payload bay and re-installed on identical interfaces in the surrogate structure. The logistics module is attached to a vacant berthing ring on the core module. Extensions of the solar array mast is achieved by EVA/MMU crewmen who transfer the folded mast segments, unfold them individually and attach them to the existing mast. The orbiter then reberths via its HPA, to the extended mast, unloads the celestial instrument and its IPS, then mounts them to the mast tip using its RMS.

INITIAL SPACE STATION ASSEMBLY OF LAUNCH 2 COMPONENTS



* ITEMS SHOWN IN PHANTOM ASSEMBLED DURING STS LAUNCH 1

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INITIAL SPACE STATION, DRY MASS SUMMARY

The dry mass data used as the program input to the space cost model are summarized in this chart.

The mass of the Initial Space Station is shown by building block module to a subsystem level. Mass estimates are based on preliminary design details and subsystem analyses; verification came from many other studies and references.

INITIAL SPACE STATION DRY MASS SUMMARY (kg)

SUBSYSTEM	3-MAN CORE	AIRLOCK	SURROGATE	EXT SUBSYS	OBSERV	LOGIS MOD
STRUCT/MECH	3650	900	964	2491	2110	1771
BERTHING/TUNNELS	900	–	–	–	–	68
SAT. SVC EQPT	–	–	1879	–	–	–
EPS	50	–	50	1800	–	50
ECLS/THERMAL	1984	–	100	–	–	125
DATA MGMT	650	–	25	–	–	–
COMM	550	–	–	–	–	15
GN&C	120	–	–	720	–	–
CREW ACCOM	1050	–	–	–	–	–
MODULE TOTAL	8954	900	3018	5011	2110	2029
STATION TOTAL	22,022					

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R-004,362.

LOW COST SUBSYSTEMS GENEALOGY

The subsystems required for the ISS (shown on this facing page) have been reviewed to determine the potential use of previously developed technology or technology currently under development. Most of the subsystems appear to be able to use equipment derived from the STS, Skylab or other ongoing spacecraft programs, and also provide growth capability. The DMS, however, would use new components or technology under development to meet the requirements of cost effective autonomy and automation. This overall assessment results in projecting a low cost subsystem development program.

LOW COST SUBSYSTEMS GENEALOGY

	POWER			DATA MGMT			EC/LS			GN&C			COMM & TRACK.		
	GEN CONT & DIST	ENERGY STORAGE	EMERGENCY	I/O & PROCESSORS	MASS MEMORY	SOFTWARE	ATMOSPHERE	WASTE MGMT	THERMAL CONT & WATER MGMT	SENSORS & PROPULSION	CONTROL	CMGs	ANTENNA PTG & TRACK	RECEIVE & XMIT	REND. RADAR
UNDER DEVELOPMENT	✓	✓		✓	✓	✓	✓		✓			✓		✓	
STS (DERIVED)			✓				✓	✓	✓	✓	✓		✓	✓	✓
OTHER SPACE PROGRAMS		✓		✓						✓	✓				
SKYLAB											✓	✓			

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SUBSYSTEM ENABLING TECHNOLOGY REQUIREMENTS

Enabling technology can encompass the complete spectrum from available off-the-shelf hardware to state-of-the-art breakthroughs. Basically the 1986 technology base and associated design techniques will satisfy the requirements for Initial Space Station and, with appropriate design considerations, will provide an orderly evolution of the Space Station. The chart on the opposite page summarizes the ISS enabling technology requirements.

SPACE STATION

SUBSYSTEM ENABLING TECHNOLOGY REQUIREMENTS

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL

	BASELINE	ENABLING TECHNOLOGY
EPS	• SOLAR ARRAY • NiH_2 BATTERIES • 180V DIST	• THIN CELL & HIGHER EFFICIENCY 2 • CELL MFG PROCESSES 2 • BATTERY DEVELOPMENT 2 • HI VOLT COMPONENT DEVELOPMENT 1
DMS	• Ada • FIBRE OPTICS • CMOS MAIN MEMORY WITH B/U BATTERY • BUBBLE AUX MEMORY	• MEETING EXISTING Ada SCHEDULE 1 • LOW LOSS COUPLERS 1 • DEV HIGHER DENSITIES 2 • SPACE QUALIFICATION & HIGHER DENSITIES 2
COMM & TRKNG	• S, K_u BAND SUBSYSTEMS • DISH, OMNI ANTENNAS • TDRS • SIMOP	• MODULATION/CODING/BANDWIDTH 1 • DES/DEV FOR APPLICATION 1 • ACQUISITION/TRACKING/DATA RATE 1 • RFI PROTECTION 1
EC/LSS	CLOSED LOOP	EXISTING HARDWARE WITH MODIFICATIONS 1
GN&C	ATTITUDE CONTROL VELOCITY CONTROL STABILIZATION SENSORS	EXISTING HARDWARE WITH MODIFICATIONS 1

1 (1983-1986) TECHNOLOGY BASE & DESIGN TECHNIQUES ADEQUATE
2 TECHNOLOGY ADVANCE REQUIRED

V83-0165-475(T)

R-004,362.

AUTONOMY & AUTOMATION

To define the degree of autonomy (ground or on-board) and automation (automatic or manned) of the Space Station, a functional analysis was performed. The functional analysis identified top level functions and the first level subfunctions to support a manned Space Station, and the various missions to be conducted on a Space Station. All of the functions were integrated into 18 major functions and 84 first-level functions. The functions were defined in sufficient detail to evaluate the degree of autonomy and automation.

The initial allocation of the functions was based on criteria that included, safety, crew capability and load, technical risk, applicability and on-board data processing load. For the 84 functions, their location and criticality were identified. Twenty-one of these functions were soft allocations, insofar as they represented judgmental allocations. These functions were subjected to a weighted trade-off by considering and quantifying, as applicable, cost, crew load, user access, reliability/maintainability, technical risk and processing load. Costs included both the development cost and the cost of operations either on-board or on the ground, and were heavily weighted. From this trade, 48 functions were determined to be onboard, 16 on the ground, and 20 shared. Each of 48 on-board functions were examined to determine whether they were manual, automatic or shared. Manual functions (5) require crew intervention (e.g., voice communicating); shared functions (19) are those that the crew interacts with automatic functions (e.g., scheduling); automatic functions (24) do not require crew participation. The results of these trades are shown on the facing page.

AUTONOMY & AUTOMATION

OBJECTIVE: DEFINE COST EFFECTIVE LEVELS OF AUTONOMY & AUTOMATION

APPROACH:

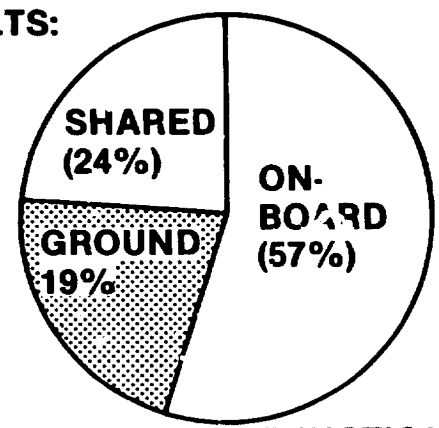
(1) IDENTIFY FUNCTIONS & FUNCTIONAL REQUIREMENTS

(2) ALLOCATE FUNCTIONS (GROUND, SPACE STATION, SHARED; MANUAL, AUTOMATIC)

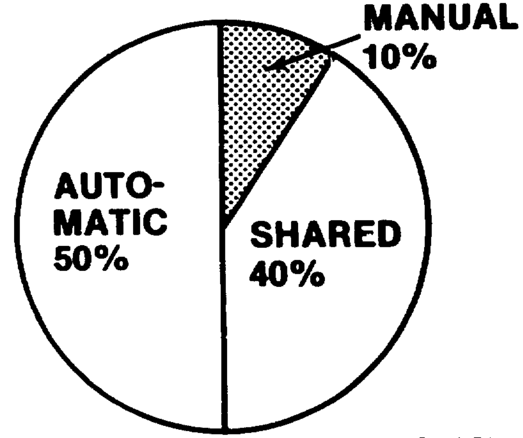
(3) EVALUATE ALLOCATION OF FUNCTIONS CONSIDERING:

- COST
- CREW LOAD
- USER ACCESS
- RELIABILITY/MAINTAINABILITY
- TECHNICAL RISK
- PROCESSING LOAD

RESULTS:



AUTONOMY (84 FUNCTIONS)



AUTOMATION (48 FUNCTIONS)

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CENTRALIZED VS DISTRIBUTED PROCESSING

Seven architectural alternatives of the on-board processing system were defined by analyzing the functional interfaces and processing loads of the 48 Space Station functions. The alternatives range from a centralized system to a fully distributed system. Each of the alternatives was evaluated using cost (hardware, software and integration), expansion potential, technology transparency, isolation of critical functions and feasibility/risk. These were combined into a figure of merit, wherein the alternative with the highest figure of merit represents the optimum distribution. Alternative 4 had the highest score. It consists of two primary processors, Station Operations and Mission Support. These processors interface together via a communication and data routing processor. Military and entertainment processors also interface through the data routing processor. The Station operations processor interfaces in turn to four processors, which in turn interface to the Space Station subsystems. The mission support processor supports common functions of the missions and provides an interface to unique mission processors, as required.

CENTRALIZED vs DISTRIBUTED PROCESSING

OBJECTIVE: DETERMINE DEGREE OF DISTRIBUTED PROCESSING

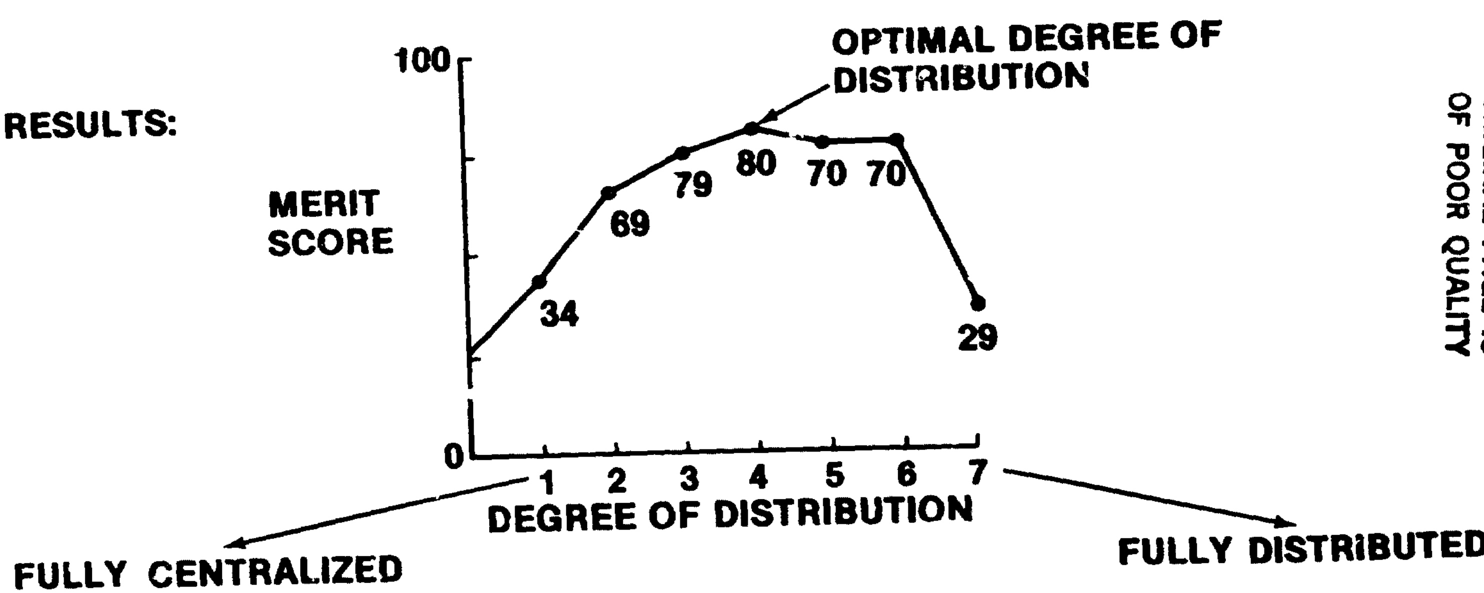
APPROACH: (1) IDENTIFY PROCESSING REQUIREMENTS FOR ALL FUNCTIONS

(2) GROUP FUNCTIONS IN VIABLE DISTRIBUTED ARCHITECTURES

(3) EVALUATE GROUPING CONSIDERING:

- COST
- EXPANSION POTENTIAL
- TECHNOLOGY TRANSPARENCY
- ISOLATION OF CRITICAL FUNCTIONS
- FEASIBILITY/RISK

RESULTS:



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EVOLUTION SCAR MASSES/COSTS

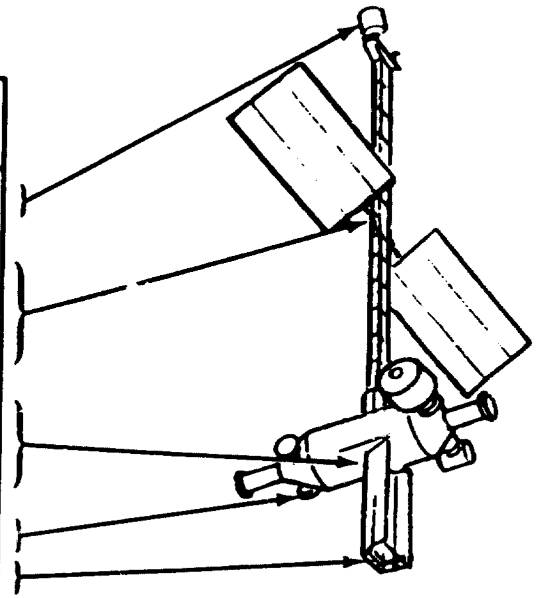
This figure identifies the effects of designing the Initial Station with a growth capability. The major impact on the mass of the station is due to oversizing to accommodate an eventual tripling of the solar arrays. The major cost impact is in the avionics, where 20% of the system is due to growth capability.

SPACE STATION

INITIAL SPACE STATION EVOLUTION SCAR WEIGHT/COSTS

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL

PLANNED GROWTH	SCAR	MASS, kg	COST, $M
OBSERV	ADDED POSITION	100	5
ELEC PWR	LONGER TOWER	250	10
	LARGER GIMBAL/INDEX	650	25
	DISTRIB OVERSIZED	330	16
AVIONICS	DATA MGMT	130	67
	COMM	90	42
SERV OPER	ADDIT BERTH POSIT	70	5
	SURROGATE ADD-ON	50	1
TRANSP		–	6
CREW SIZE	ADD. CREW CAPAC	–	–
	TOTALS	1670	177



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SCAR
1700 LB/$200M

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R-004,362.

EVOLVED SPACE STATION AT 28.5 DEG

The initial Space Station can grow incrementally to the Evolved Space Station configuration shown here. Two standard three-man habitation core modules are added to the complex to house six more crewmen. Two core modules, modified to be laboratories, are added for science and industrial processing R&D. The modules are attached to each other by tunnels that extend from each cone end, providing redundant escape paths from each module, and inter-module traffic flow that is clear of the main activities areas. The outboard tunnels can mount logistic modules, air locks and growth modules.

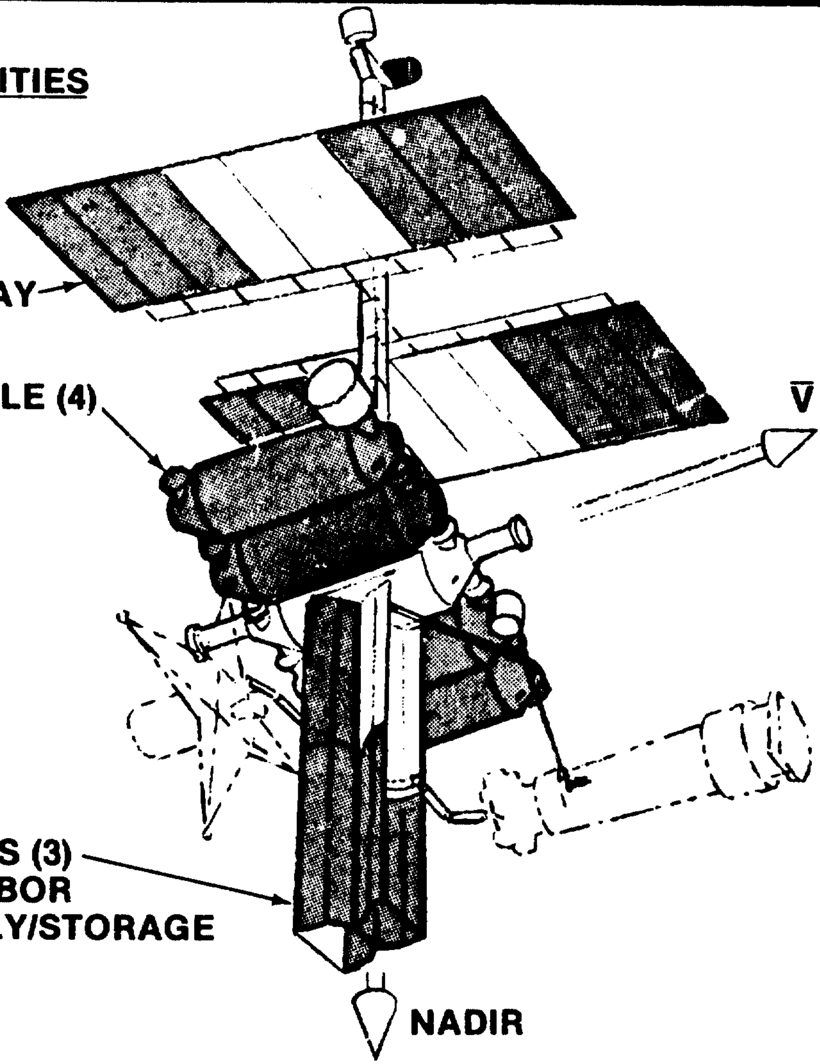
Additional surrogate structures, installed back-to-back, provide increased facilities for satellite service, space test and the transport harbor, which must now accommodate OTV turnaround activities. These additions can be accomplished from an orbiter berthed to the core module tunnel extension.

The solar array trebles incrementally in size and in power output from Initial to Evolved configuration. These increments are installed by a tethered EVA crewman on his MMU/WRU transferring each folded solar array panel to its mount on the cross arm, then actuating its SEPS-type deployment.

EVOLVED SPACE STATION AT 28.5° INCLIN

ADDED FACILITIES

- SOLAR ARRAY
- CORE MODULE (4)
  - HAB (2)
  - LAB (2)
- SURROGATES (3)
  - OTV HARBOR
  - ASSEMBLY/STORAGE



- CREW SIZE = 9
- POWER = 66 kW
- MASS = 51,300 kg
- ADD–ON COST = $1.69 B
- TOTAL COST = $5.97 B
- TYPICAL MISSIONS
  - ASTRONOMY
  - LIFE SCIENCE
  - R&D
  - OTV/POV/TMS TURNAROUND
  - SATELLITE & INDUSTRIAL PLATFORM SERVICE
  - PAYLOAD ASSEMBLY
  - EARTH OBSERVATION

C-2

V83-0165-913(T)

R-004,362.

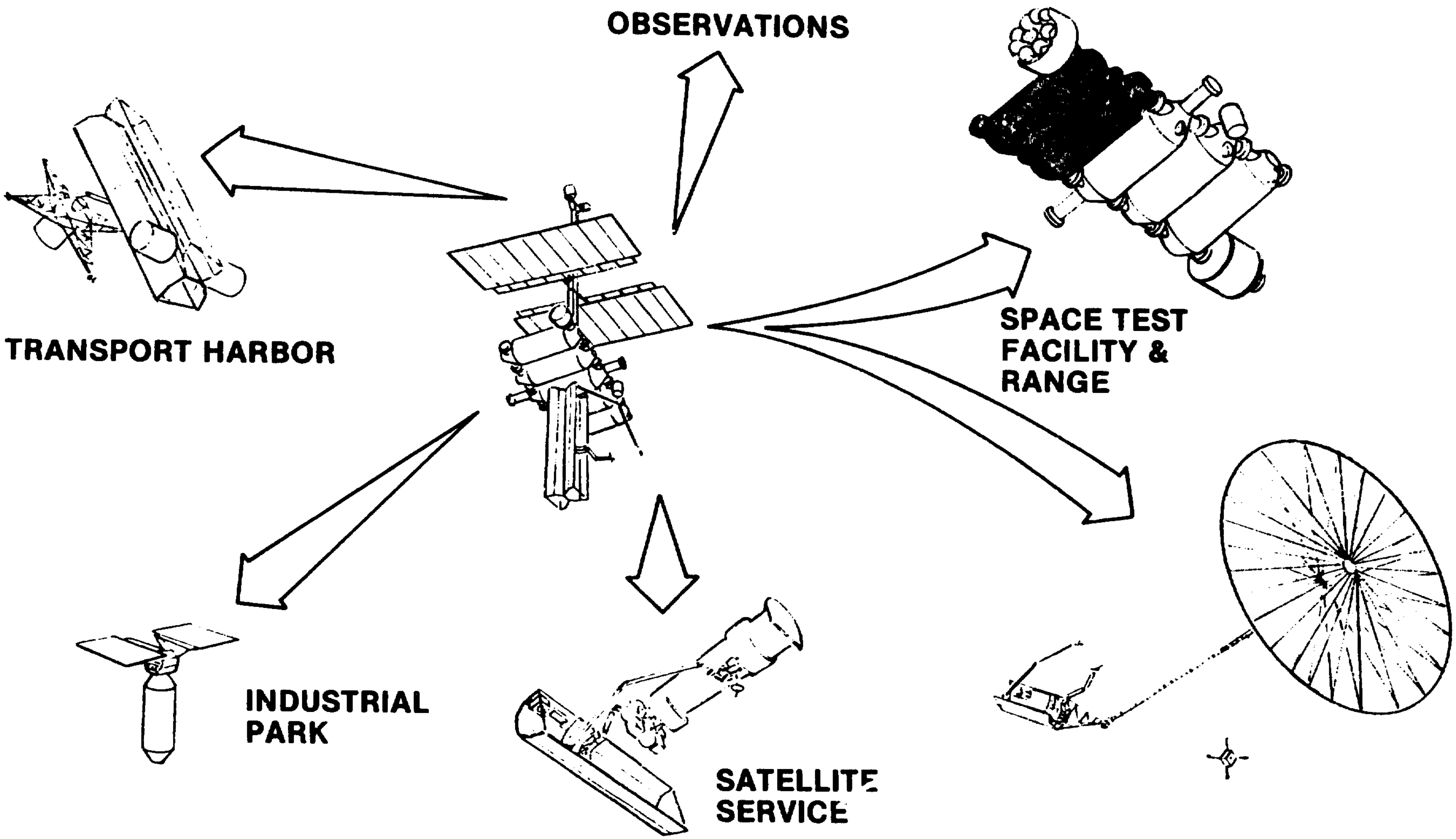
MISSION FUNCTIONAL CAPABILITIES

The functional capabilities necessary for performing missions on the Space Station are illustrated on this chart. Celestial observations are performed outboard of the solar arrays since they need clear viewing for 2π steradians, anti-earth. Satellite service facility, in general, shares with the space test range but, if more convenient for a particular test, the transport harbor can accommodate a test activity. The industrial park is berthed to the core module for exchange of processed materials, but its subsystems are serviced at the transport harbor.

The transport harbor is primarily to turn around an OTV which uses storable propellant and is refuelled by removing the empty propellant tank and replacing it with a ground-filled tank.

Laboratories for R&D are shown shaded in the grouping of core modules.

MISSION FUNCTIONAL CAPABILITIES



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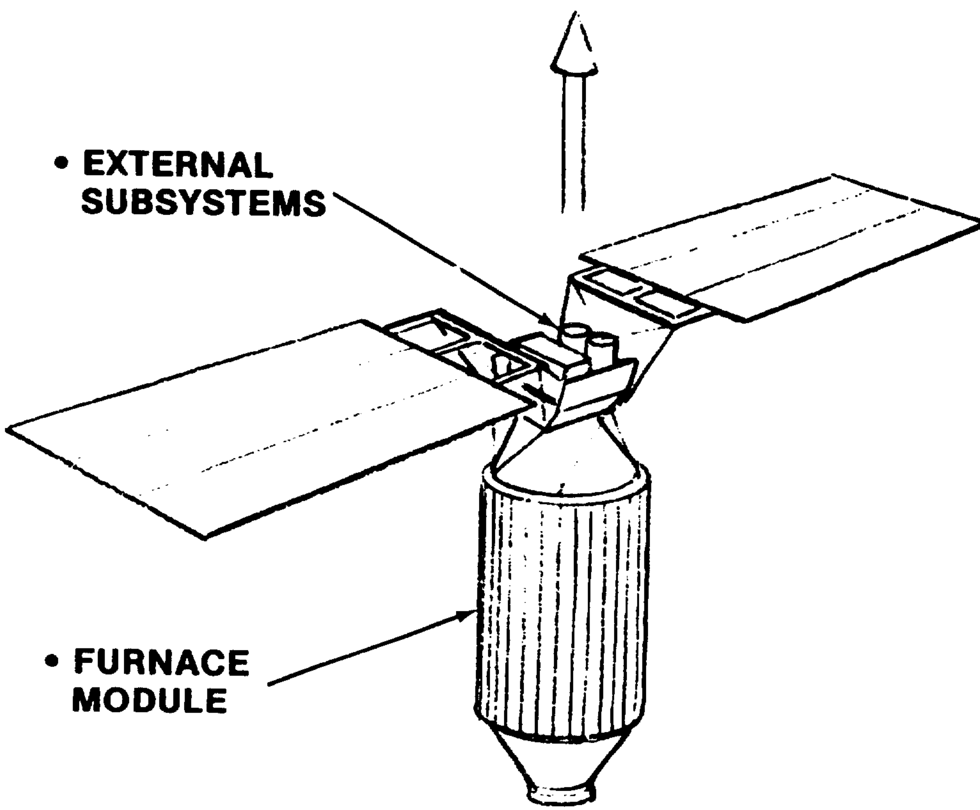
TENDED INDUSTRIAL PLATFORM

Micro-g requirements and very high power demands for materials production are difficult to satisfy as part of the main Space Station. Therefore, the materials processing facility is an industrial park of free flyers that co-orbit with the main station.

Four free flyers will be required for the program, and this chart illustrates a typical one. The pressurized core module used for habitations and laboratories on the Space Station provides the pressurized shell and appropriate subsystems. Necessary additional subsystems will be installed in the module. As with the main station, a pallet mounts such external subsystems as batteries, power processing and cmg's. The solar array power source has no gimballing requirements, since the satellite will be flown inertially fixed relative to the sun, thus simplifying the array and minimizing potential undesirable accelerations.

Allocation of the potential 40 processing units to the four free flyers will be on the basis of duty cycle. Therefore, the power requirement for each will vary with a total requirement of around 110 kw continuous. The average is 28 kw per free flyer and that is the size of the array shown.

TENDED INDUSTRIAL PLATFORM



- IVA TENDED WHEN BERTHED TO STATION
- POWER = 28 kW
- MASS = 9,800 kg
- COST = \$(0.40 + 0.39 n)B
- MISSION = COMMERCIAL MATERIAL PROCESSING

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FORMATION FLIGHT & OPERATIONS CORRIDORS

Operational sequence of a free flyer is such that it boosts itself to a higher orbit using onboard propulsion. The new orbit is dictated by the duty cycle time of the furnaces, because the flyer is allowed to orbit decay in that time period so that at the end of the duty cycle its location is suitable for rendezvous, capture and berthing to the Space Station for materials exchange and servicing of subsystems.

This figure illustrates the industrial park complex interfacing with the Space Station. A sector of space trailing behind Space Station, for example, is used for their formation flight. The free flyers are deployed into relative trajectory paths such that they traverse to within close proximity of the Space Station at the prescribed time intervals. The free flyers would be cycled such that only one would arrive or depart at the Space Station on any given day. To set-up this flight formation corridor requires a region about the Space Station bounded by a few kilometers above and below and extending behind to about 2000 km.

SPACE STATION

FORMATION FLIGHT & OPERATIONS CORRIDORS

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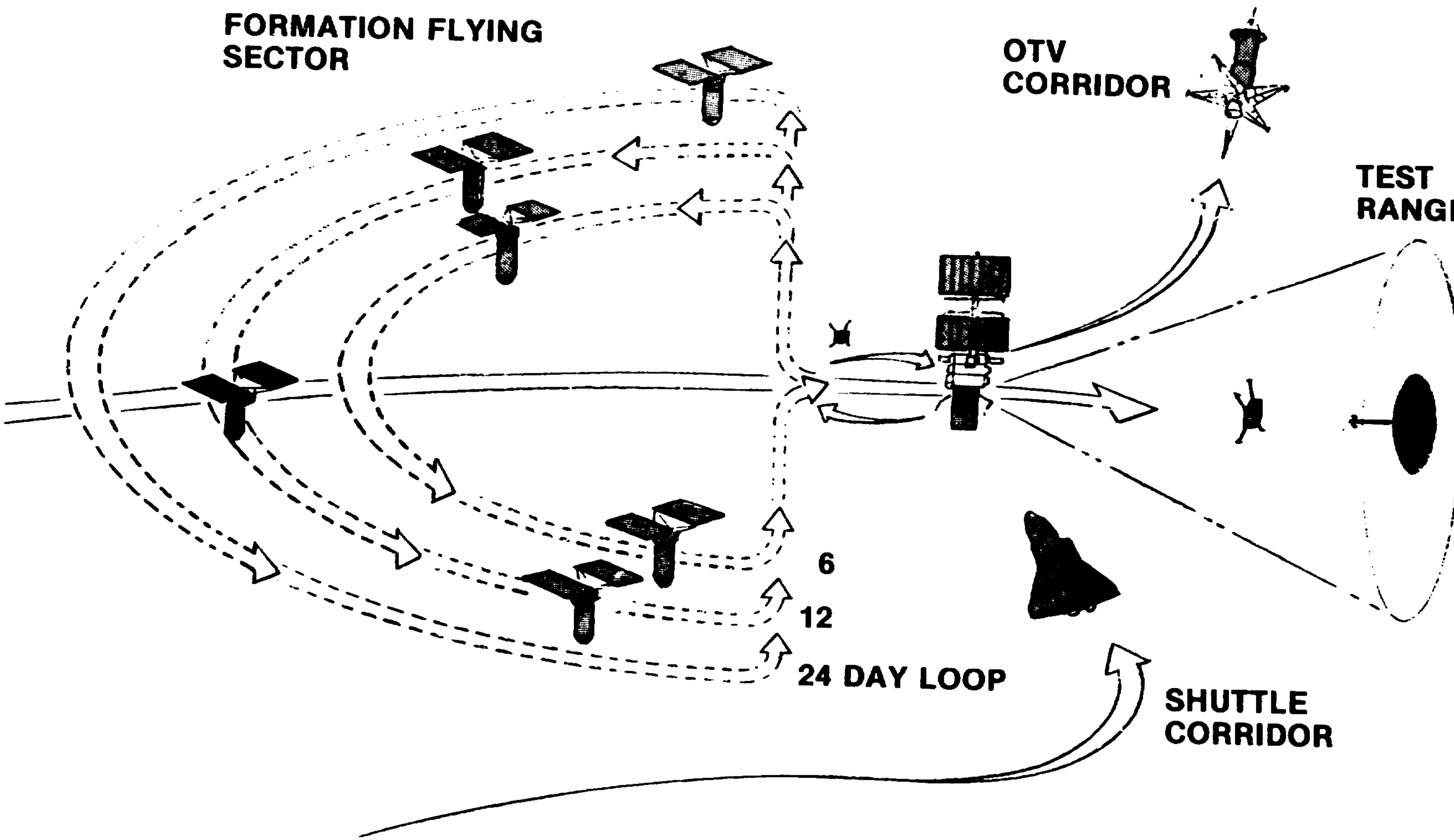
COMSAT GENERAL



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TENDED POLAR PLATFORM, INITIAL

Requirements call for a total of three astrophysics, three solar and 12 terrestrial observation missions to be aboard a LEO facility in high inclination orbit by the year 2000. Some of the earth observation missions dictate a noon sun synchronous orbit, to provide light/dark contrasts.

System analysis shows that an unmanned platform, visited by the Shuttle at approximately six-month intervals to service the platform change out observation instruments and service satellites, can satisfy the missions.

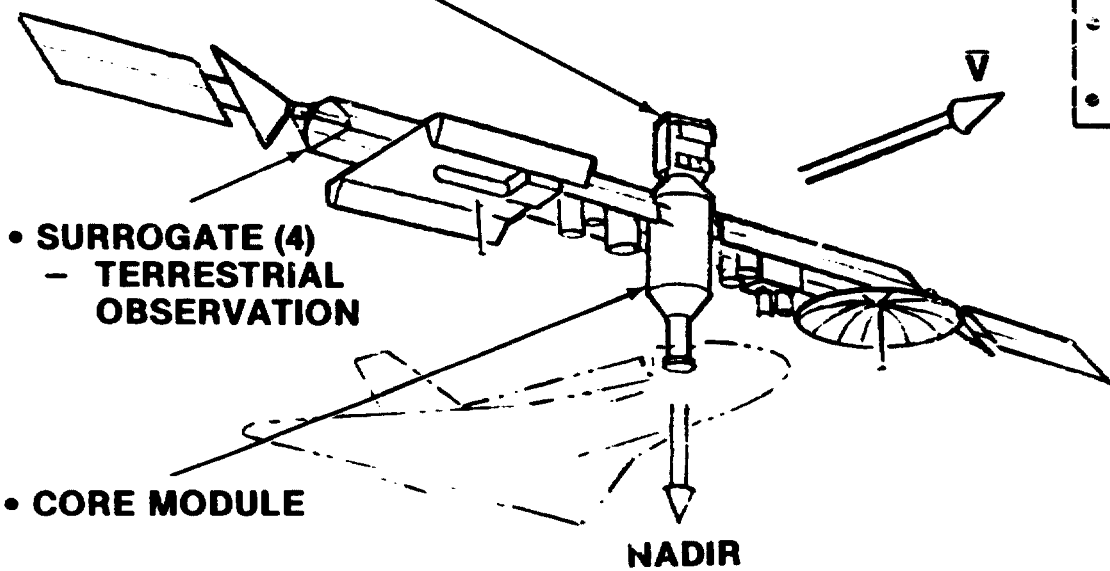
Initially, the platform caters to earth viewing and is configured as shown here. A standard three-man habitation module, replicated from the 28.5 deg inclination Space Station, houses subsystems and can provide extended living volume for a visiting orbiter crew. When visiting, the orbiter berths to the module to enable shirt sleeve servicing of the subsystems.

Surrogate bay structures mount IPSs that, in turn, mount the packages of earth observation instruments. Solar array panels are mounted outboard of the surrogates on structures designed to support solar observation instruments at a later date. The array is sized to give 14.5 kw of continuous power.

An external subsystems pallet mounts batteries for dark side power, conversion equipment and control moment gyros for attitude control.

TENDED POLAR PLATFORM – INITIAL

- CREW SIZE = 3
- POWER = 14.5 kW
- MASS = 24,400 kg
- COST = $0.76 B
- MISSION = EARTH OBSERV



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TENDED POLAR PLATFORM, EVOLVED

The evolved Polar Platform is shown here. To accommodate the full complement of earth observation missions, a surrogate bay structure is added orthogonally to the two existing structures. Another surrogate is added to mount satellite service equipment. These are added directly from the orbiter berthed to the pressure module extension tunnel.

From this same berthed orbiter location, a tethered EVA crewman with an MMU , transfers folded mast segments one at a time to construct a mast outboard of the external subsystems pallet. The mast tip mounts a celestial observation instrument which requires a viewing field of 2π steradians, anti-earth.

Solar array wings are extended by adding panels to provide a total continuous power of 29 kw. IPS-mounted solar viewing mission equipments are located on the solar array wings support structures. Their gross pointing is provided by the solar array gimbal.

Two celestial observation packages are mounted to the back, anti-earth face of the surrogate structures. Their viewing requirement is local zenith and, therefore, they are located outboard of the volume swept out by the movements of the mastmounted celestial instrument.

Berthing points for the orbiter will be provided on the mast and surrogate structures. The orbiter can berth its HPA end effector to a suitably located point, to enable its RMS to reach for adding the celestial and solar observation equipment and to extend the solar arrays.

SPACE STATION

TENDED POLAR PLATFORM EVOLVED

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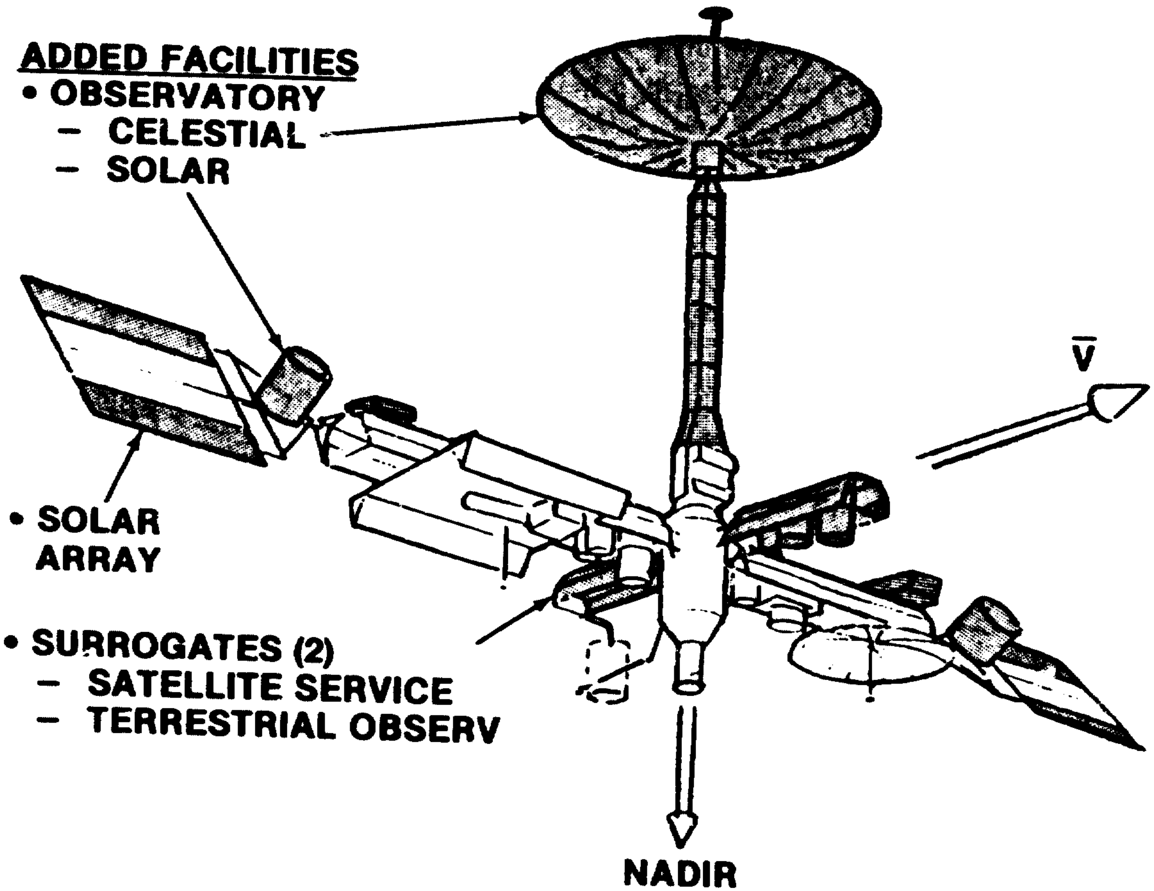
COMSAT GENERAL



- CREW SIZE = 3
- POWER = 29 kW
- MASS = 40,300 kg
- ADD–ON COST = $0.44 B
- TOTAL COST = $1.20 B
- TYPICAL MISSIONS
  - ASTRONOMY
  - EARTH OBSERV
  - SOLAR OBSERV
  - SATELLITE SERVICE

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KEY TECHNOLOGY ISSUES

In addition to the enabling technology defined earlier, other key technology issues have been identified. Considered early in the program, these issues can provide significant performance, operation and cost benefits. They are shown on the facing page in order of relative importance based on our judgment of their program benefits. They range from programmatic considerations (such as the development and maintenance of attractive user accommodation criteria) through the generic subsystem issues such as autonomy, automation and in-orbit maintenance and repair. The list is not all inclusive. There are numerous subtasks of specific technology issues (such as zero-g fluid transfer, total H_2/O_2 systems, etc), which should be addressed in the appropriate technical discipline areas.

KEY TECHNOLOGY ISSUES

- ATTRACTIVE USER ACCOMODATIONS CRITERIA
  - SIMPLIFIED & BROAD INTERFACES (MOUNTING, THERMAL, POWER, DATA)
  - COMMON INTERFACE ADAPTORS/INSTRUMENTATION
  - SIMPLIFIED & EXPEDITIOUS STATION ACCESSABILITY
- "COST EFFECTIVE" PROCEDURE FOR SOFTWARE DEVELOPMENT, CHECKOUT MAINTENANCE & CONTROL
- POLICY FOR AVIONICS INTEGRATION & CONFIGURATION CONTROL
  - HANGAR QUEEN/INTEGRATION LAB/CONTRACTOR FACILITIES
- TDAS TO/FROM SPACE STATION ENHANCED TELEMETRY
- REUSABLE SPACE BASED OTV DEVELOPMENT
- SUBSYSTEM DEVELOPMENT (TEST BEDS) FOR:
  - AUTONOMY/AUTOMATION
  - INORBIT MAINTENANCE & REPAIRS
  - TECHNOLOGY TRANSPARENCY
  - LONG TERM OPERATION
  - MAN/MACHINE INTERFACES
  - STANDARDIZED INTERFACES

FINAL SUMMARY BRIEFING
AGENDA

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- INTRODUCTION & CONCLUSIONS
- REQUIREMENTS
- ARCHITECTURE & TECHNOLOGY
- **COSTS & BENEFITS**
- SUMMARY RECOMMENDATIONS

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KEY COSTING GROUNDRULES

A primary factor in a traceable and credible parametric cost analysis is a well defined set of groundrules. These are detailed in the Cost/Programmatic volume, and the key groundrules are shown on the facing page.

All costs are normalized to constant FY 1984 dollars using the NASA escalation factors supplied. Since detailed designs were not required or desired, weight-based parametric cost estimates were used to estimate the rough order of magnitude costs provided.

Module level costs are provided in all cases. Most of the estimation was performed at the subsystem level, and these are shown. Costs include contractor G&A, but exclude fee.

The organization followed the Work Breakdown Structure developed by the joint Industry Government Space System Cost Analyses Group (SSCAG).

Costs were estimated at the most likely weight, and no contingency weight allowance was made.

A flightworthy spare was estimated to cost 60% of the Theoretical First Unit cost, and added to the estimated production cost.

Transportation to LEO was included in the production cost totals. Facility costs were not estimated, and the NASA wraparound costs were estimated and reported but were not included in the totals.

KEY COSTING GROUNDRULES

- FY 84 CONSTANT $ (NASA ESCALATION FACTORS)
- MODULE LEVEL COSTS (ALL CASES)
- SUBSYSTEM LEVEL COSTS WHERE ESTIMATED (MAJORITY)
- COSTS INCLUDE CONTRACTOR G&A, EXCLUDE FEE
- COSTS AT MOST LIKELY WEIGHT, NO CONTINGENCY
- FACILITY COSTS NOT ESTIMATED
- NASA WRAPAROUNDS REPORTED SEPARATELY

SPACE STATION SUMMARY, ACQUISITION COSTS

The initial Space Station in the 28.5 deg orbit will encompass a full range of capabilities; it is expected to consist of a three-man Habitat, External Subsystems and Power Supply, Surrogate Modules for Satellite Services and Transportation Harbor, an Observation Module, and a Shuttle-borne logistics module for regular resupply functions. The DDT&E phase for the Initial Station is estimated to be \$3.2B, and production will be \$1.1B, for a total acquisition cost of \$4.3B.

The augmented capability station additions to be phased in later will require an additional \$0.4B DDT&E, and \$1.3B for production. Four Tended Industrial Platforms complete the 28.5 cluster, for an additional \$0.4B DDT&E and \$1.5B production cost. Thus the total acquisition cost for the mature 28.5 deg Station is anticipated to be \$7.9B.

The initial high-inclination Tended Polar Platform is expected to have a DDT&E cost of \$0.6B and a production cost of \$0.7B, with a later DDT&E add-on for augmented capability costing, an additional \$0.6B, and \$0.4B production cost.

The total acquisition costs for the mature 28.5 deg Station and the mature Polar Platform is expected to be \$9.1B.

SPACE STATION

SPACE STATION SUMMARY, ACQUISITION COSTS 1984$ MILLIONS

GRUMMAN
GENERAL ELECTRIC
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	PHASE	DDT&E	PRODUCTION*	TOTAL
28 1/2	INITIAL SPACE STATION	3165	1114	4278
	SPACE STATION ADD ON	376	1312	1688
	INDUSTRIAL PLATFORM (4)	404	1546	1950
	TOTAL	3945	3972	7916
POLAR	INITIAL TENDED POLAR PLATFORM	57	702	759
	POLAR PLATFORM ADD ON	57	382	439
	TOTAL	114	1084	1198
	TOTAL	4059	5056	9114

*INCLUDES TRANSPORTATION TO LEO

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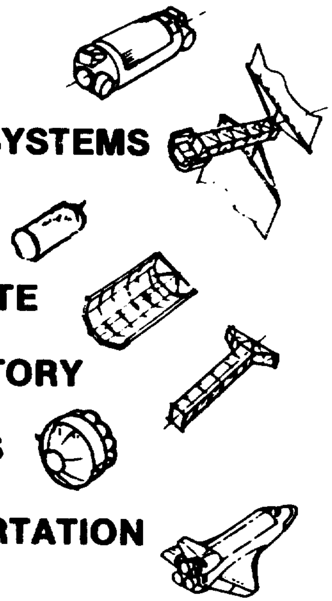
MASS/COST SUMMARY, ISS

The Initial Space Station's costs and masses are summarized by modules, as shown.

These are parametric data for a dry Station which requires two initial Shuttle launches ($84M each) and thereafter the use of three logistic vehicles for resupply and crew rotation ($328M). These result in an inclusive cost of $4300M, with an accompanying mass of 22,000 kg.

MASS-COST SUMMARY INITIAL SPACE STATION



MODULE	MASS, kg	DDT&E, $M	NO. OF UNITS	PRODUCTION, $M	TOTAL TO IOC, $M
HABITAT	8954	$\boxed{1702}$	1	$\boxed{386}$	$\boxed{2088}$
EXT SUBSYSTEMS	5011	624	1	351	975
AIRLOCK	900	–	1	22	22
SURROGATE	3018	400	1	90	490
OBSERVATORY	2110	179	1	30	208
LOGISTICS	2029	260	3	68	328
TRANSPORTATION	–	–	–	168	168
TOTALS	22,022	3165		1115	4280

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INITIAL SPACE STATION, HABITAT MODULE COST BREAKDOWN

The Habitat Module costs are broken down into two categories, a Spacecraft Segment, and Integration and Test at System Level, in accordance with the modified SSCAG WBS.

The Spacecraft Segment is further subdivided into hardware, software, services and GSE. The hardware is subdivided into Integration Assembly and Checkout (IACO) and subsystems. As is the usual practice in an indented WBS arrangement, each level of indent sums to the next higher level, as shown.

The Habitat Module is estimated to require $1.7B for DDT&E and $0.4B to produce, giving a total acquisition cost of $2.1B.

INITIAL SPACE STATION HABITAT MODULE COST BREAKDOWN

SPACE STATION

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GENERAL ELECTRIC
COMSAT GENERAL

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	DDT & E				PRODUCTION			
HABITAT	$1702M				$386M			
SPACECRAFT		1445				386		
HARDWARE			840				339	
IACO				79				41
SUBSYSTEMS				761				297
SOFTWARE			150					
SERVICES			278				47	
GSE			177					
INT & TST, SYS LVL		257						

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INITIAL SPACE STATION, HABITAT MODULE SUBSYSTEM COST

The bulk of the cost estimating was accomplished by using subsystem level Cost Estimating Relationships (CERs). As an example of this level, we show the subsystems included in the Habitat Module cost breakdown. The acquisition cost of this module's subsystems is anticipated to be $0.8B for DDT&E and $0.3B for production. These costs are summed with the Integration, Assembly and Checkout (IACO) costs to form the hardware part of the spacecraft's Habitat Module.

INITIAL SPACE STATION HABITAT MODULE SUBSYSTEM COST

	DDT & E	PRODUCTION
SUBSYSTEMS	$761M	$297M
STRUCTURE	69	28
BERTHING	0	3
EPS	4	3
ECLS	211	76
THERMAL CTL	3	14
CONTR & DISPLAYS	11	5
DATA MGT	182	56
COMMUNICATION	190	60
GN & C	4	11
CREW ACCOM.	50	19
TUNNEL	35	21

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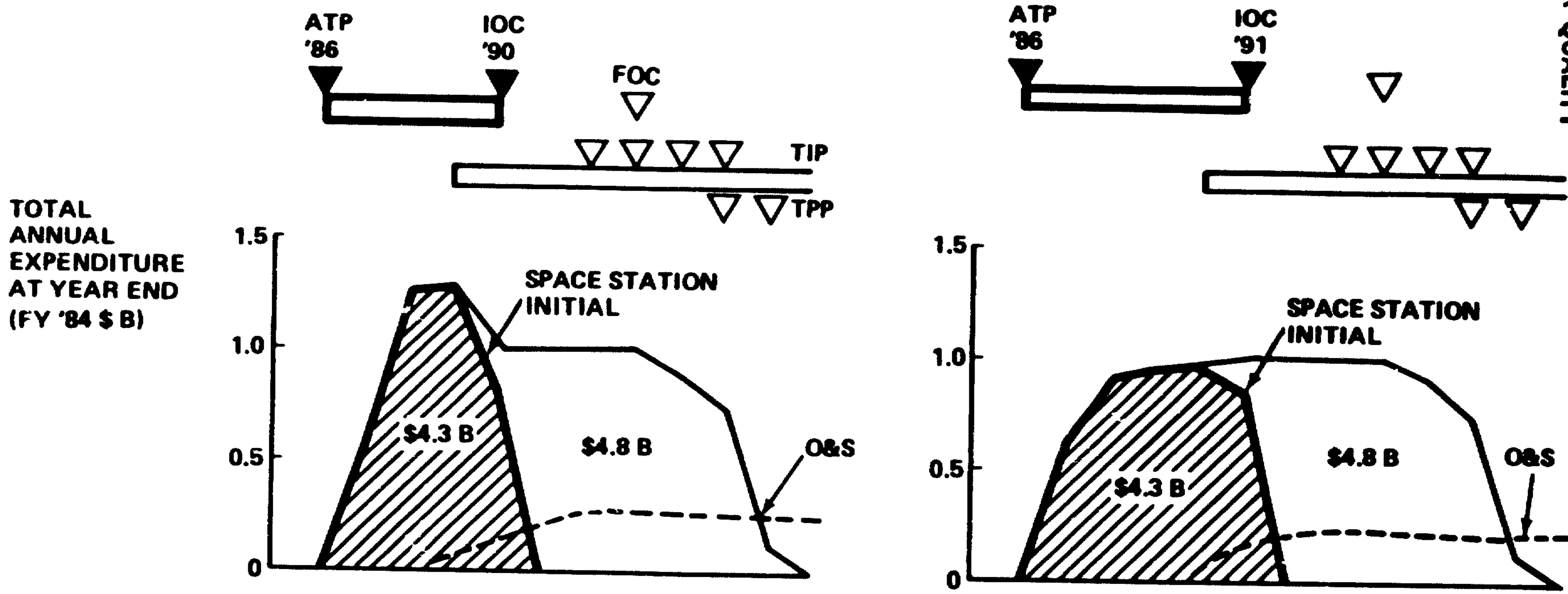
SPACE STATION FUNDING PROFILE

Assuming a thorough Phase B effort, and an Approval To Proceed (ATP) at the end of FY'86, the Baseline Schedule calls for an initial operational capability (IOC) of the Initial Space Station at the end of FY'90. This four-year period is about the minimum time reasonably expected without a strenuous "crash" type program. On the average, Phase C/D aircraft programs run about two years from ATP to first flight, with that for LM and Shuttle being about eight years.

The funding profile for this baseline program, however, reveals two disadvantages. First, the rapid buildup of expenditures may cause difficulties, and the peak annual funding comes to about \$1.3B in FY'89, which exceeds the desired limit of \$1.0B.

A program delaying the Initial Space Station IOC from the end of FY'90 to FY'91, with a corresponding postponement of deployment of the Evolved Station, the Tended Industrial Platforms and the Tended Polar Platform yields a program conforming to the \$1.0B peak annual funding requirement.

SPACE STATION FUNDING PROFILE



NASA INITIAL SPACE STATION ACQUISITION OPTIONS

In examining the projected cost involved in producing the Initial Space Station, consideration was given to the proposition that some (if not all) parts of the Station might be "farmed out" to large contractors, a consortium, or foreign interests who would finance and develop these parts or modules, being repayed by a lease or barter arrangement.

The Logistics Module ($328M) and the Surrogate Module ($489M) appear to be within the financial capability of large aerospace contractors, or a consortium of them. To reduce the NASA "up-front" cost, it might be quite feasible for such a contractor or consortium to design, qualify and build these modules and lease them to NASA for operation. A foreign government might participate with a barter arrangement.

This scheme has the potential of offloading $817M from the NASA investment. It must be observed, however, that lease costs would increase operating costs. Assuming a 20-year life and 30% return before taxes, the annual lease cost would be approximately $30 per $100 invested. Thus NASA would pay out the investment cost in slightly over three years, and the contractor would recoup his investment, after taxes, in about six years, which is about as long as any entrepreneur would find attractive.

A more modest proposition would be to develop such participation in the supply of such "detachable" hardware as berthing ports, pallets, airlocks, etc. A total potential offload of $70M is available using this scheme. The net effect would be to reduce NASA "up front" costs from $4.3B to $3.2B.

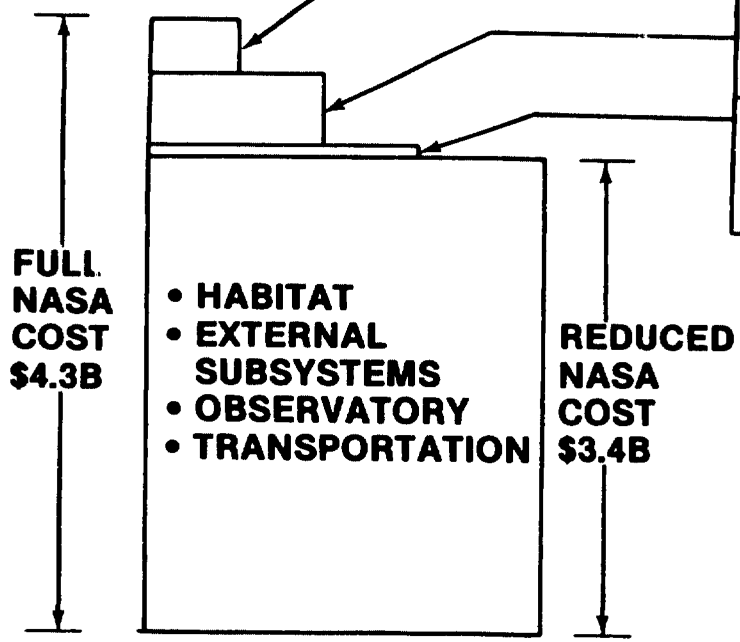
SPACE STATION

NASA INITIAL SPACE STATION ACQUISITION OPTIONS

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL

ELEMENT	INVEST-MENT	POTENTIAL INVESTOR	ANNUAL OPERATIONS COST IMPACT
LOGISTICS	$328M	INTL BARTER COMM VENTURE	$100M
SURROGATE	489	DoD or COMMERCIAL VENTURE	150
DETACHABLE* HARDWARE	70	COMMERCIAL VENTURE	20
	$887M		$270M

*NASA DEVELOPED



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NASA SPACE STATION GROWTH ACQUISITION OPTIONS

As the Space Station evolves into its mature growth configuration, additional opportunities for non-NASA participation presents themselves. Three of these are of particular interest.

The first is the R&D facility, which has a total cost of $824M (including its share of the add-on Habitat, External Subsystems and Transportation costs). These latter costs are estimated to be $339M, with the Laboratory Module share at $485M. This module may be a candidate for international participation, or possibly DoD sharing, with a potential offload of the $485M from the NASA investment. The annual impact on operating costs was calculated as before (30% return, 20-year life, or $145M).

With the same approach, the transport harbor initial investment of $1064M might be offloaded by $825M if DoD funds this effort, or possibly a commercial venture.

The third element is the Tended Industrial Platform complex, with a total cost of $2180M and an offload potential of $1952M.

It is obvious that many other options and arrangements are possible and feasible; these should be explored.

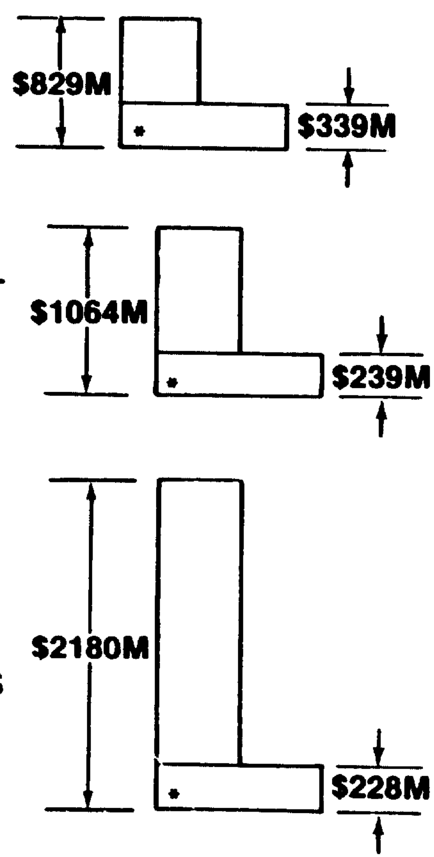
NASA SPACE STATION GROWTH ACQUISITION OPTIONS

NASA COST: FULL REDUCED

R&D FACILITY

TRANSPORT HARBOR

TENDED INDUSTRIAL PLATFORMS (4)



	INVESTMENT	POTENTIAL INVESTOR	ANNUM OPN COST IMPACT
LABORATORY	$485M	INTL DoD	$145M
OTV (2)	$825M	DoD	($250M)
PLATFORMS	$1952M	INTL COMM VENTURE	$590M

*ADD ON HABITAT, EXTERNAL SUBSYSTEMS, & TRANSPORTATION SHARE

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SUMMARY OF SOME PROGRAM OPTIONS

The program options involving international participation, DoD involvement and commercial and industrial cooperation are virtually without number. These avenues should be explored in depth as the program proceeds, not only to ease the NASA investment, but also to insure that the beneficiaries of the Space Station participate in the planning and investment.

This chart indicates that the Initial Space Station total NASA investment of $4.3B may be reduced to $3.4B with others participating. With suitable participation (primarily DoD), a duplicate 28 5 deg Station might be possible for a total investment of $4.0B.

The "normal" evolution of the Initial Space Station to the mature system with associated industrial platforms and the Polar Platform may be possible with a NASA investment of $5.8B, vs the required $9.9B if no participation is obtained.

PARTIAL PROGRAM OPTIONS SUMMARY

INITIAL STA	DUPLICATE	TRANSP HARBOR	SERV & ASSY TEST, OBSV	INDUST PLTFMS (4)	POLAR PLTFM	NASA TOTAL INVESTMENT ($B): NASA ALONE	NASA TOTAL INVESTMENT ($B): OTHERS PARTICIPATING
4.3 / 3.4						= 4.3	3.4
4.3 / 3.4	+ 0.8 / 0.6					= 5.1	4.0
4.3 / 3.4		+ 1.0 / 0.2				= 5.3	3.6
4.3 / 3.4		+ 1.0 / 0.2	+ 1.2 / 0.7			= 6.5	4.3
4.3 / 3.4		+ 1.0 / 0.2	+ 1.2 / 0.7	+ 2.2 / 0.3		= 8.7	4.6
4.3 / 3.4		+ 1.0 / 0.2	+ 1.2 / 0.7	+ 2.2 / 0.3	+ 1.2 / 1.2	= 9.9	5.8

LEGEND: NASA ALONE INVESTMENT → x
y ← NASA INVESTMENT, OTHERS PARTICIPATING

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ACCRUED ECONOMIC BENEFITS

The economic benefit analysis was performed by calculating the incremental investment required to provide each operating facility of the Space Station (i.e., R&D facility, Service/assembly facility, Transport Harbor and Observatory and the platforms). For typical missions, costs were estimated using the Space Station, and by the best non-Space Station means. The benefit was considered to be the difference between the two costs. The benefits were then accrued according to the mission model plan.

The test facility was found to have a very rapid payoff (two years) when military and civil missions were considered. The Transport Harbor payoff is also quite fast, (three years) and is expected to continue to rise as traffic develops.

The service/assembly and observatory facilities show less spectacular, though quite satisfactory payback characteristics, four and five years, respectively.

SPACE STATION

ACCRUED ECONOMIC BENEFITS, SPACE STATION AT 28.5° INCLIN

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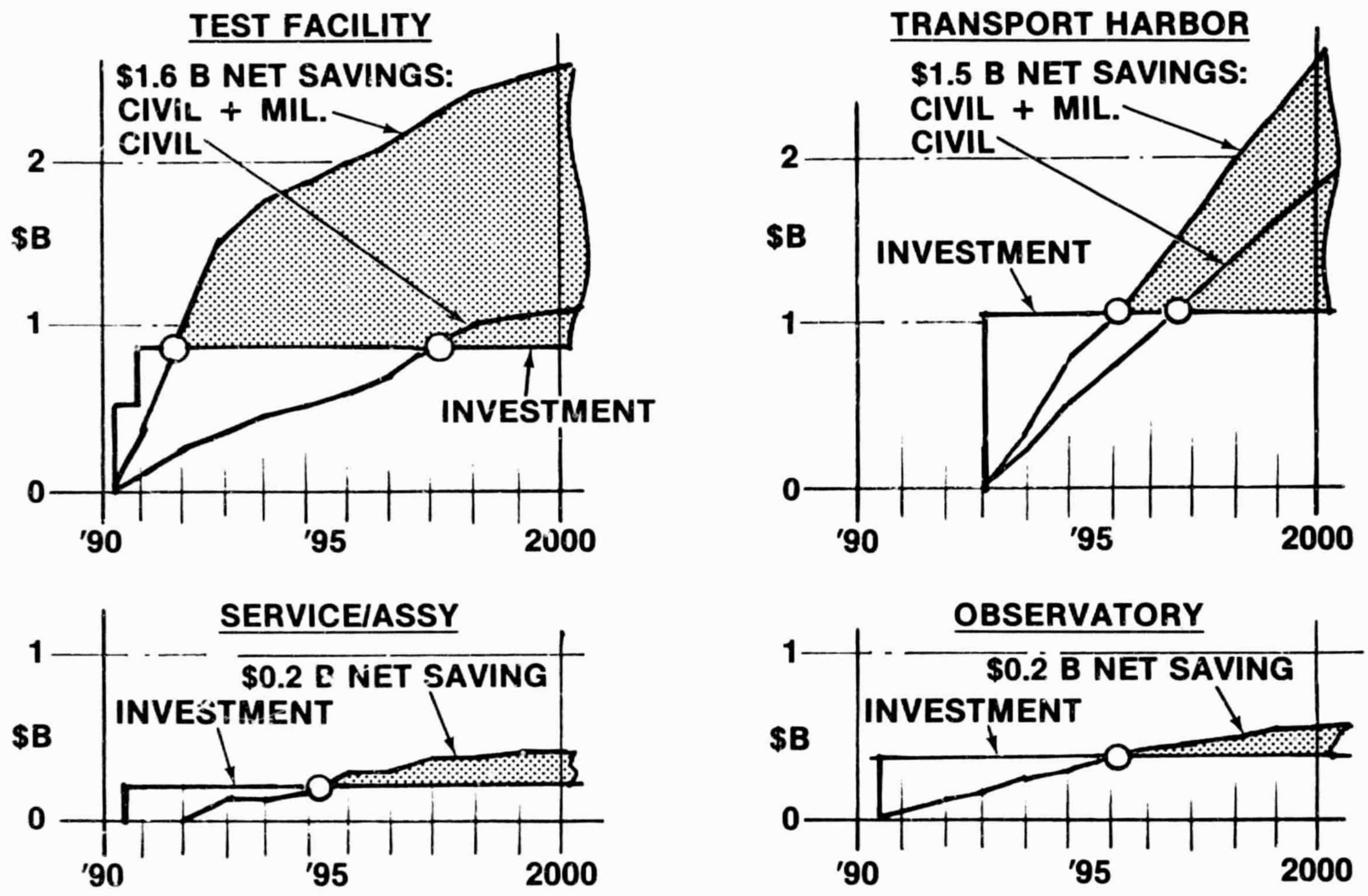

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ACCRUED ECONOMIC BENEFITS (CONTD)

The Tended Platforms, Industrial Park and Tended Polar Platform show very acceptable payoffs (six and four years, respectively). Benefit of the Industrial Platform may be expected to continue to rise as experience is gained in its use, and a broader constituency is developed.

The observatory accrued benefit is not expected to exhibit the exponential growth shown by the Industrial Park, but is expected to be more stable as shown.

SPACE STATION

ACCRUED ECONOMIC BENEFITS, TENDED PLATFORMS AT 28.5° & 97° INCLINS

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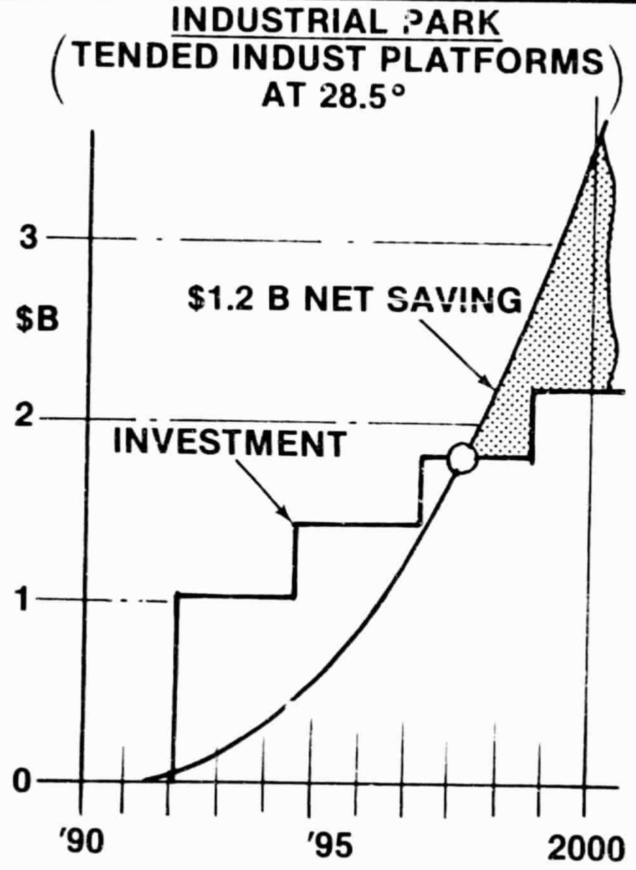

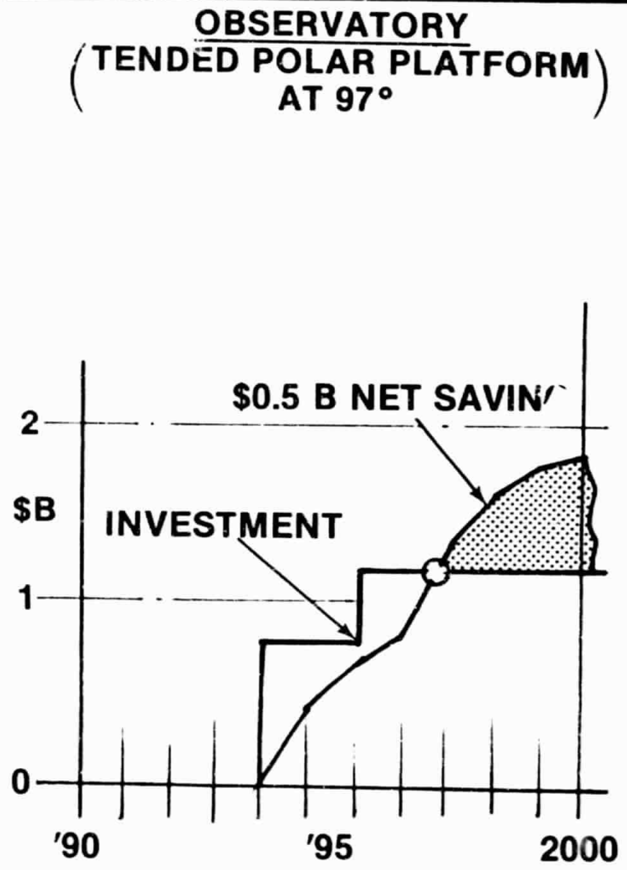

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MILITARY SPACE STATION FUNCTIONS WITH HIGH PAYBACK

As shown in detail in the accrued benefit analysis, the most attractive Space Station capabilities for the military are the test laboratory/test range facility and the space-based OTV.

The former yields a significant decrease in development time and cost for military developments, and the latter offers significant savings in transport from LEO to high-inclination orbit or GEO.

SPACE STATION

MILITARY SPACE STATION FUNCTIONS WITH HIGH PAY-BACK

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GENERAL ELECTRIC
COMSAT GENERAL

STATION CAPABILITY	MISSION	PAY-BACK
▷ NATIONAL SPACE TEST FACILITY & RANGE	• ENGINEERING DEV • PROOF OF CONCEPT	26% OF SPACE TEST COSTS SAVED
▷ TRANSPORT HARBOR & SPACE-BASED OTV	• SATELLITE DEPLOYMENT TO GEO	PAYBACK IN > 4 YEARS, CIVIL/MILITARY TRAFFIC

DoD INVOLVEMENT AS ON SPACE SHUTTLE

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PERFORMANCE BENEFITS

All mission operations will benefit from the reduced impact on mission operations caused by Shuttle reschedules, payload priorities or delays. This will be especially significant as the Station matures and develops its full capability of crew and equipment.

We anticipate that the current trend of making larger satellites will be encouraged by the capability of lifting large payloads to GEO, and that such satellites will be designed with that in mind.

The on-orbit assembly capability affords an economical method for very large structures without Shuttle-size limitations, excessive Shuttle loiter time and extensive EVA activities.

In two of our studies, development programs were reduced 50% by Space Station use.

PERFORMANCE BENEFITS

▷ALL MISSION OPERATIONS	• DECOUPLED FROM SHUTTLE LAUNCH SCHEDULE, PAYLOAD PRIORITIES, & GROUND DELAYS
▷SPACE BASED OTV	• 10,000 kg + USEFUL PAYLOAD INTO GEO • ON-DEMAND CAPABILITY
▷ON-ORBIT ASSEMBLY	• ASTRONAUT CAN INSPECT, WORK AROUND, & COMPLEMENT ROBOTICS & AUTOMATION • SHUTTLE SIZE LIMITS SURMOUNTED
▷ON-ORBIT TECHNOLOGY AND R&D	• ASTRONAUT CAN CALIBRATE, OPERATE, & MODIFY • TRUE SPACE ENVIRONMENT • INTERACTION OF MULTIPLE DISCIPLINES & CAPABILITIES IN A NOVEL ENVIRONMENT WILL PRODUCE SYNERGISTIC ADVANCES • SHORTER DEVELOPMENT PROGRAMS
▷SCIENTIFIC OBSERVATIONS	• SHORT LIVED EXPERIMENTS EXTENDED • ASTRONAUT CAN MONITOR, INTERVENE, REPLENISH, & UPDATE.

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SOCIAL BENEFITS

The social/societal benefits to be expected from implementation of a viable Space Station program, although difficult to quantify in precise terms, are none the less real, important and of considerable magnitude.

This nation has been in the forefront of high technology development, and this is an implicit and explicit national goal. The Space Station augments the national capabilities for high technology in a very significant manner, and provides a focus for what some feel is our lagging engineering and science educational aims.

International cooperation has been generated by the shuttle program, and the Space Station can provide a much greater and broader stimulation for international cooperation.

In terms of a unique development facility, there can be no earth-bound parallel. The possibilities for development of communication services, commercial products, and industries in the semiconductor and medical fields are all realizable benefits.

New therapeutic and diagnostic techniques have been demonstrated by limited Shuttle experiments, with a Space Station offering vastly augmented capabilities. The Space Station may well represent the military "high ground" required for our security.

These near-term benefits lead to the inevitable conclusion in the long term, the Space Station is truly the "gateway to the future."

SOCIAL BENEFITS

IN THE SHORT TERM:

- HI-TECH – A NATIONAL GOAL
- FOCUS FOR ENGINEERING/ SCIENCE EDUCATION
- UNIQUE LUNAR & BEYOND EXPLORATION
- INTERNATIONAL COOPERATION
- UNIQUE, AFFORDABLE DEVELOPMENT FACILITY
- NEW COMMUNICATION SERVICES
- NEW COMMERCIAL PRODUCTS & INDUSTRIES – MEDICAL, SEMI-CONDUCTOR
- NEW THERAPEUTIC, DIAGNOSTIC TECHNIQUES
- ENHANCED NATIONAL SECURITY

IN THE LONG TERM:

- GATEWAY TO THE FUTURE

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FINAL SUMMARY BRIEFING AGENDA

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INTRODUCTION & CONCLUSIONS

REQUIREMENTS

ARCHITECTURE & TECHNOLOGY

COSTS & BENEFITS

SUMMARY RECOMMENDATIONS

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CONCLUSIONS

The Initial Space Station should be manned, placed in 28.5 deg orbit and provide capabilities with high payoff in economic, performance and social benefits. The potential accrued gross mission model benefit derived from these capabilities is \$5.9B without the industrial park, and \$9.3B with.

Using the Space Station as a national space test facility will enhance national security, commercial and scientific interests alike. Adding the other capabilities (i.e. , Transportation Harbor, servicing and assembly, etc), provides a focal point for high technology development and spin-off to the private sector. These new capabilities lead to a number of benefits: it affords more science to be done earlier; it lowers the cost (34%) of high performance transport to orbit; it lowers the acquisition cost for future NASA and DoD space assets; it fosters commercial development of new products and new communication services; it enables the development of new energetic technologies (sun pumped laser and plasmas); and it allows unique lunar and beyond exploration. A vigorous Space Station program will not only rekindle national interest and education in science and engineering, but will also provide a basis for broadening international cooperation.

CONCLUSIONS

- SPACE STATION PROVIDES SIGNIFICANT BENEFITS (ECONOMIC, PERFORMANCE, & SOCIAL)
  - ACCRUED GROSS MISSION MODEL BENEFITS:
    $5.9 – 9.3 B (28.5° WITHOUT & WITH IND PARK)
    $9.3 – 11.0 B (28.5° + POLAR PLATFORM)
  - AFFORDS MORE SCIENCE EARLIER
  - FOSTERS COMMERCIAL SPACE DEVELOPMENT (26 – 70% LOWER COSTS: 15 – 53% FASTER)
  - GROWING INTEREST FOUND IN NON-AEROSPACE COMMUNITIES
  - ENABLES DEVELOPMENT OF NEW TECHNOLOGIES
  - LOWERS COST 34% WITH HIGH PERFORMANCE TO ORBIT
  - LOWERS ACQUISITION COST FOR FUTURE DoD & NASA SPACE ASSETS (26% REDUCTION IN SPACE TEST COSTS)
  - ALLOWS LARGE EXPLORATORY SYSTEMS TO BE IMPLEMENTED
  - STIMULATES NATIONAL INTEREST & TECHNOLOGY EDUCATION

CONCLUSIONS (CONTD)

The Initial Space Station should be manned, placed in 28.5 deg orbit, and provide capabilities that include space test facility, satellite service, transport harbor and observatory. The chief emphasis is on external activities and reinforces the point that the next U.S. Space Station must be more than "man-in-the-can" and thus, must go beyond such previous manned programs as Skylab and Salyut.

The concept of building incrementally from "initial" to "evolved" Space Station carries a penalty on the initial station of 1700 kg of weight and a cost of $200M.

Our studies have revealed no technology show stoppers.

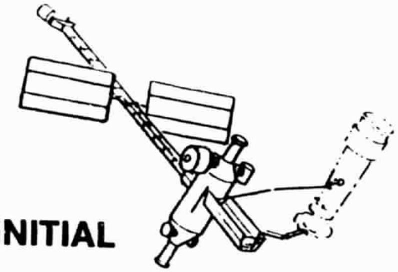
CONCLUSIONS (CONTD)

- RECOMMENDED ARCHITECTURE TO MEET MISSION REQUIREMENTS
  - INITIAL SPACE STATION SHOULD BE AT 28.5°, MANNED & PROVIDE HIGH PAYOFF CAPABILITIES

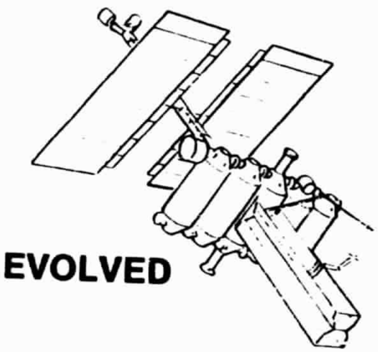
	SPACE STA	SKYLAB	SALYUT
TEST FACILITY	✓	✓	✓
RANGE	✓	–	–
TRANSHARBOR	✓	–	✓
SAT. SERVICE	✓	–	–
OBSERVATORY	✓	✓	✓

  - INCREMENTAL CONCEPT DERIVED MEETS VARYING FUTURE CUSTOMER NEEDS

(INITIAL SCAR 1700 kg
$ 200M)



INITIAL



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- NO TECHNOLOGY SHOWSTOPPERS

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CONCLUSIONS (CONTD)

As we have defined our concept, the development, production and launch costs of the Initial Station amount to \$4.3B (FY'84 dollars). The investments required for any subsequent growth, when kept small by adhering to the architectural replication strategy, can be fully recovered within a few years from the Space Station operational savings.

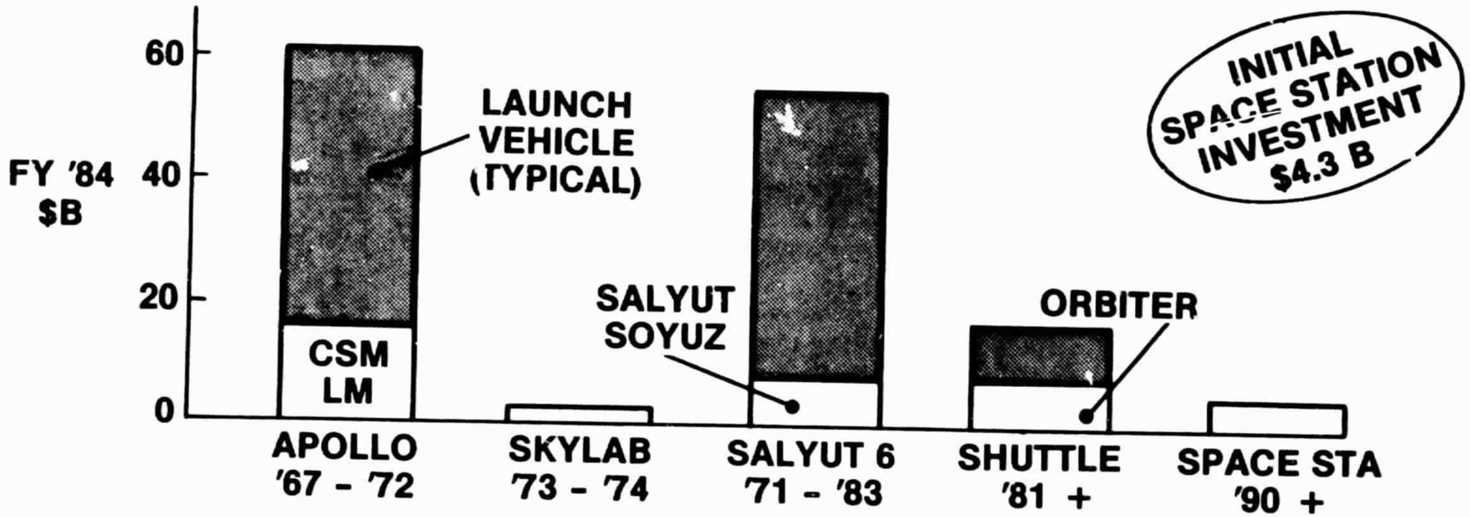
We believe that the initial \$4.3B should be treated as a sunk cost. It should be noted that this sum is quite small when compared with Apollo, Skylab, Salyut or Shuttle. In addition, there are practical opportunities for NASA to reduce its initial investment by up to \$0.9B by international, commercial and national security participation in the program.

SPACE STATION

CONCLUSIONS (CONT)

GRUMMAN
GENERAL ELECTRIC
COMSAT GENERAL

- PROGRAM OPTIONS DEFINED FOR INITIAL SPACE STATION ACQUISITION



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- PRACTICAL OPPORTUNITIES TO REDUCE NASA INITIAL INVESTMENT
  - INTERNATIONAL PARTICIPATION
  - COMMERCIAL PARTICIPATION
  - NATIONAL SECURITY PARTICIPATION

  $\left.\begin{array}{l}\\ \\ \\ \end{array}\right\}$ \$0.9 B

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RECOMMENDATIONS

- MAINTAIN MOMENTUM OF USER COMMUNITIES IN SPACE STATION STUDY
  - INVOLVEMENT IN REQMTS/CONCEPT
  - STIMULATE NEW PARTICIPANTS
  - DEVELOP NEW WAYS OF DOING BUSINESS
- STRENGTHEN NASA-DOD EVOLUTIONARY STUDY ACTIVITY FOR DEEPER PENETRATION OF AREAS FOR MUTUAL GAIN
  - MIXED PAYLOAD MISSIONS
  - R&D CAPABILITY DEFINITION
  - OPS SUPPORT
- CONTINUE TO INVOLVE INTERNATIONAL COMMUNITY IN SPACE STATION STUDY — PROMOTE INDUSTRY TO INDUSTRY INTERACTION

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RECOMMENDATIONS CONT'D

- DEVELOP LOW. ENERGY TRANSFER TUGS (POV & TMS) FOR IN-FLIGHT TURNAROUND
- DEVELOP SPACE BASED OTV FOR ITS HIGH PAYOFF
- CONTINUE US INDUSTRY PARTICIPATION IN SPACE STATION REQMTS DEFN & CONCEPT DEVELOPMENT
  - STOP-GO ACTIONS DISCOURAGE CORPORATE INVOLVEMENT IN FORMATIVE STAGES
  - TIME PHASING ISSUE WITH INTERNATIONAL STUDIES
  - INDUSTRY PROVIDES NEEDED EXPERTISE WHICH WILL NOT BE EXPLOITED BY IN-HOUSE GOVT TEAMS
- UNDERTAKE AN ORBIT OPERATIONS DEVELOPMENT ON SHUTTLE TO PREPARE FOR SPACE STATION IMPLEMENTATION
  - DEVELOP CAPABILITIES
  - DEMONSTRATE FEASIBILITY FOR DECISION MAKERS OF FUTURE ASSETS

SPACE STATION GATEWAY TO THE FUTURE

It is clear from the work accomplished by the Grumman team that the most beneficial Space Station capabilities include space test facility, transport harbor, satellite service and observatory. A space industrial park may be added in the future, once further development effort validates the cost and expanding commercial market for space-processed material. Man's presence in orbit will greatly enhance mission performance in many operational activities. Interactive control of robotic devices and automatic equipment aboard the Space Station allows man's capabilities to be used in the most beneficial manner.

These new capabilities lead to a number of benefits, such as: it affords ore science to be done early; it lowers the acquisition cost for future NASA and DoD space assets; it fosters commercial development of new products and new communication services; and it allows unique lunar and beyond exploration. A vigorous Space Station program will not only rekindle national interest and education in science and engineering, but will also provide a basis for broadening international cooperation.

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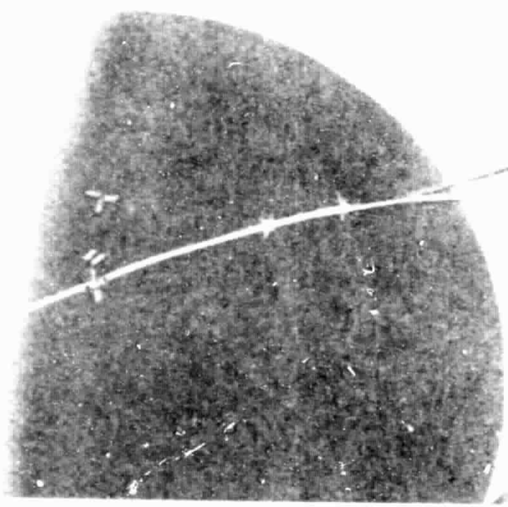
SPACE STATION

SPACE STATION GATEWAY TO THE FUTURE

GRUMMAN

NEW CAPABILITIES

- NAT'L SPACE TEST FACILITY
- TRANSPORTATION HARBOR
- SATELLITE SERVICING & ASSY FACILITY
- OBSERVATORY
- INDUSTRIAL PARK
- INTEGRATED ROLES — MAN & ROBOTICS



LEAD TO

- HI-TECH — A NATIONAL GOAL
- ENHANCED NATIONAL SECURITY
- NEW COMMERCIAL PRODUCTS
- NEW COMMUNICATION SERVICES
- UNIQUE LUNAR & BEYOND EXPLORATION
- LARGE AFFORDABLE SPACE SYSTEMS
- STUDENT INCREASE-ENG'G & SCIENCE
- INTERNATIONAL COOPERATION